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ORR'S
CIRCLE OF THE SCIENCES.

ORR'S
CIRCLE OF THE SCIENCES :

A Series of Treatises

ON

THE PRINCIPLES OF SCIENCE,

WITH THEIR APPLICATION TO PRACTICAL PURSUITS.

—◆—
ORGANIC NATURE.

VOLUME II.
—◆—

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A

SYSTEM OF NATURAL HISTORY:

BEING

A STRUCTURAL AND CLASSIFIED ARRANGEMENT OF
PLANTS AND ANIMALS,

FORMING

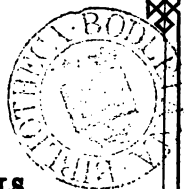
A Basis for the Study of Botany and Zoology.

WITH NUMEROUS MICROSCOPIC AND OTHER ILLUSTRATIONS.

IN TWO VOLUMES.

VOL. I.

BOTANY AND INVERTEBRATED ANIMALS.



BOTANY,
BY EDWARD SMITH, M.D., LL.B.

ZOOLOGY,
BY W. S. DALLAS, F.L.S.

LONDON:
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MDCCLV.

PREFACE.

THE following Treatises are devoted to the consideration of the structure of Plants and Animals; and it has been the aim of the authors to write with scientific accuracy, and with sufficient detail, without introducing discussion upon contested subjects. They trust that the work will be found intelligible to the unlearned, and instructive to those also who have obtained an elementary knowledge of the subjects.

Occasional observations will be met with, by which the reader is reminded that Plants and Animals are not only parts of the same great Creation; but that so closely are some plants associated with the so-called higher kingdom, that no definite line of demarcation can be drawn between them. It is for this reason that the reader is advised to study Botany in connexion with Zoology; and it is probable that a closer acquaintance with the structure and functions of certain parts of plants will ultimately enable us to trace more correct as well as more striking resemblances between the members of the two kingdoms than have as yet been conceived. For example, no nerves, or analogues of nerves, have as yet been found in plants; and yet it is quite clear that not only is a low degree of vital sensibility as universal in plants as in animals; but that in certain instances, as in the sensitive plant, it is developed to a far greater extent than is perceptible in animals taken from the lowest point in the scale of animal life.

This mode of investigation will give greater breadth and interest to the study of Natural History than the more simple and yet more difficult one of studying the parts of plants or of animals as detached points bound together by no universal law; and it is one, moreover, which tends to train the mind to habits of reflection as well as of observation. The authors have endeavoured to aid the mind in this search by introducing a very large number of microscopic and other illustrative engravings, which have the merit of showing the extreme beauty and elegance of design existing in the composition of plants, and offer many new points for analogical comparison with the exquisitely minute structures of animals. A microscope is now as necessary to the naturalist as a telescope to the astronomer.

In the remarks on Classification, the author of the Treatise on Botany has been drawn, by force of circumstances, to give much prominence to the Linnæan system; and this is the less to be regretted, since the analysis of the system, and the directions which follow it, may suffice to enable the reader to enter upon the study with facility, and to learn almost without trouble the positions of nearly all the most important plants of native origin. He will also find not only that there is a similarity between plants and animals from the presence of vital functions—viz., those of reproduction, respiration, circulation, digestion, growth, and decay—but that the very structures which give them bulk and form have in many instances close analogical resemblances. Thus the simple cell, which is the universal basis of animal structures, is, in like manner, and in equal degree, the universal basis of vegetable tissues. The thick-walled cells are very like to bone cells, the milk-bearing vessels to capillary blood-vessels, and their milky juice to the chyle or digested food of animals. Many other parts are analogous to those of animals in appearance; whilst others, again, are like them in function.

In accordance with the train of reasoning which this close connexion between Plants and Animals suggests, the ordinary method of arranging the animal kingdom has been reversed; the arrangement adopted having the obvious advantage of bringing together those plants and animals which so closely resemble each other as to render it sometimes doubtful to which of the kingdoms of Nature they belong.

With these few remarks we conclude the Natural History of PLANTS and INVERTEBRATED ANIMALS. The remaining portion of Organic Nature, which embraces the higher forms of animal organization, commencing with the Fishes and terminating with Man, will be concluded in another volume.

LONDON, *January*, 1855.

—sefer—

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BOTANY.

THE objects which we now proceed to contemplate have exceeding interest, not only in themselves, but in their relation to the other parts of this fair creation, and more especially to man. They were the first vital existences which appeared when the fiery mass which constitutes the earth had become covered with a stony crust of a cooler temperature, and they are the last to linger when the rigours of a Polar clime chase away all vitality. They are still the sole inhabitants of isolated spots on the burning plains of central Africa, and are the harbingers of animal life on the remotely issued lava, and the more recently emerged coral island of the southern seas.

They are found universally within limits bounded, on the one hand, by the perpetual snows of the Arctic regions, or the summits of our own Snowdon; and, on the other, by the parched sands of tropical deserts; and cover, as with a carpet, the magnificent prairies of India and America, the wild haunt of the buffalo, or jealously hide the long-lost cities of Assyria, which once teemed with wealth and myriads of human beings as busy as ourselves. Not only do they exist upon the surface of the soil, but their remains constitute a large part of the soil itself; so that seeds, which subsequently germinated, have been thrown up from considerable depths, after having lain buried more than two thousand years. The solid crust of the earth is also, in part, of vegetable origin, as in the instance of the widely-spread coal-beds, with their remains of primeval forests. Moreover, the very air which covers the earth is not free from these objects; and the waters of the rivers and the seas abound in vegetable life.

They offer the most wonderful diversities of features and proportions. There are the varied flowers which, as the daisy and buttercup, form the nosegay of infancy and the garland of youth; as the sweet violet which, on its mossy bank, sheds perfumes

on the loves of gentle maidens; as the blooming rose which adorns the bridal, and as the gloomy cypress which guards the tomb. There are the microscopic mould, which lends age to our mouldering ruins; and the gigantic forest-trees which, in the penal settlement of Norfolk Island, soar to the height of more than two hundred feet; or the celebrated chestnut-tree of Mount Etna, which sheltered one hundred horsemen.

They exist of every age, from the cell of the mushroom, which perishes in an hour, to the hoary Baobab of Senegal, which is computed to have lived since long before the days of Abraham. They quietly submit to the revolutions of centuries, with the changes of clime; and, as in the case of our own England, when the heat ceases to give life to cocoa-nut bearing palm-trees, and tree ferns, they gradually and silently appear as the modest primrose or the sturdy oak. They had traced long eras of the world's history when no human being marked their form; and they will, doubtless, bear testimony to the progress of events until time shall be no longer. The antiquity of the blade of grass is far higher than that of the noblest families.

They have done essential service to their more highly endowed cousins of the animal kingdom, by having, directly or indirectly, fed all and clad many. They have formed the shelter of men and animals, and the chief part of the utensils and instruments of the former since his creation; and, even in our day, are presenting new treasures of infinite value for his use, as in the India-rubber and gutta-percha, so recently derived from their juices.

Thus the objects of our investigation should lose no dignity when we remember their remote antiquity, their universality, variety, beauty, and utility.

The consideration of these objects constitutes the science of Botany—a science which may be more exactly said to treat of plants, their internal and external parts, general and medical properties, geographical distribution, and classification. We purpose, in this essay, to limit our attention to the first and last portions of the subject—viz., the anatomy and classification of plants.

History of the Science.—The various considerations which we have already adduced, may enable us to conjecture that this science, in its rudimentary condition, must have existed from remote antiquity. If any further evidence short of direct proof were wanting, it might be gathered from the pages of sacred history, in which we find a constant reference to this division of created existences. The first authentic records on this subject are connected with the Grecian and Roman eras, and extend as far back as about the sixth century before Christ. The cultivators of the science did not then receive the wide appellation of Botanists, but the more humble and restricted one of *Rhizotomæ*, or root-cutters; since they chiefly directed their attention to the medicinal properties of plants.

Aristotle, of Stagira, who lived in the fourth century before Christ, is regarded as the founder of the science of botany; and from his days, through the Grecian, Roman, and Arabian eras, down to the eleventh century, considerable additions were made to their knowledge of this subject. Amongst those who cultivated this science most successfully, we may instance Mithridates, and several Grecian kings, with the younger Juba, king of Mauritania. These potentates established botanical gardens—partly, no doubt, from the love which they bore to the science, but in the instance of some of them, at least, more with a view to the cultivation of the deadly plants from which the poisonous juices were derived which killed Socrates, and which, at that period, was not an uncommon mode of execution. Tyrtamus, of Lesbos, who accompanied Alexander the Great in his victorious progress

through some of the regions of Asia and Africa which now acknowledge the British sway; Nicander of Colophon, Cato, Varro, Columella, Virgil, Pedacius, Dioscorides of Silicia, who followed the Roman armies in their expeditions during the fourth century; and, lastly, the elder Pliny. Up to this period, therefore, we owe our knowledge of botany to the Greeks and Romans; and then, as now, war, notwithstanding its desolation, was made to promote the interests of science.

The Arabians, in the eleventh century, were the next cultivators of botany, as they were the most learned people then existing. After them the darkness of the middle ages set in, during which no science was cultivated, except by a monk, here and there, secluded in his gloomy cloister; and it was not until the rise of the illustrious Marco Polo, of Venice, that the darkness became dispelled. He examined the treasures of middle and southern Asia, and the eastern coasts of Africa, and described plants from India and the Indian Ocean. From his days to the present the science has progressively advanced; first, in the addition to our knowledge of the names of plants, and, secondly, of their structure and physiology. The Italians, and then the Germans, in the sixteenth century, rendered good service to the science, as did also, at the same period, the Portuguese by their conquests in India, and the Spaniards by their discovery of America.

From this and the succeeding century the science of botany, as it is now understood, may fairly be dated; since then, for the first time, an attempt was made to classify the plants which had been discovered and named, and the microscope enabled them to analyze the minute structures. Our own country now claims a distinguished share in the honours of discovery. The Society of London for the Promotion of Science, which was liberally supported by Charles the Second, gave much attention to the subject, and more particularly its secretary, Nehemiah Grew, who published his observations on the "Anatomy of Plants" in 1682. Another of our countrymen, Robert Morison, Professor at Oxford, distinguished himself in the department of classification, by the publication of various works, and especially of his "*Historia Plantarum Universalis*," with plates, in 1716. He was quickly followed by a yet more distinguished man, John Ray, an English clergyman, who enunciated the true principles of classification, and demonstrated the sexual characters of plants. Dr. Hans Sloane, the President of the Royal Society, who died in 1753, and John Parkinson, the Superintendent of the Medical Botanical Garden at Chelsea, and several successors of the latter, were honourably distinguished.

We have not space to enumerate even the most distinguished names which have adorned this science during the past two centuries. It must suffice to state that the great Linnæus, a native of Sweden, is by far the most eminent, and established the sexual system which now bears his name. After him came De Saussure and Du Hamel, Link, Rudolphi, Mirbel, Kieser, Schleiden, Darwin, and Quekett, in reference to anatomy and physiology, and Jussieu, De Candolle, Robert Brown, Sowerby, Sir J. E. Smith, Sir W. Hooker, Sir J. Paxton, and Lindley, in reference to classification. No country has a greater claim to boast of the advantages which it has rendered to botanical science than our own. It has established the best botanical gardens, as the Royal Gardens of Kew and of Hampton Court, and the Medical Botanical Gardens at Chelsea; and it has led the way in the investigation of minute structure. At the present moment, it claims a multitude of most distinguished men labouring in one or other of the departments of the same field.

Definition of a Plant.—Definitions are at all times difficult, and not the less so that they appear easy. In this instance, as the three great kingdoms of nature pass

so insensibly the one into the other, it is impossible to show, with rigorous certainty, where the one ends and the other begins. It is a curious fact that, as science is extended and knowledge is increased, our difficulties arising from ignorance are increased in at least an equal proportion. Years ago the definition of a plant was not considered impossible; but now he would be thought a rash man who should attempt a satisfactory definition of a mineral, a plant, or an animal. This is one of the evidences that knowledge was intended to humble us by showing us our ignorance. The saying of Linnaeus,—that minerals grow, plants grow and live, animals grow, live, and feel,—is now held to be an insufficient definition. The value of this terse mode of expression is concealed in the assumption that the properties thus added in succession do not belong in any degree to the classes preceding. Thus all three classes grow, but only two live, and only one feels. This is now known to be incorrect. Thus, certain



Fig. 1.—*DIONÆA MUSCIPULA*, OR VENUS' FLY-TRAP.

A, the three sensitive hairs on the expanded leaf.

B, a fly entrapped by the folding of the lobes of the leaf.

live, feel, and move. On the other hand, the sponges (Fig. 3), in their developed state,



Fig. 2.

Ciliated spores of the *Confervæ*, which at this stage of development have a degree of locomotion by means of the hairs or cilia attached to them.

are denied the faculty of locomotion, although they undoubtedly belong to the animal kingdom.

These characters having failed to mark the distinction between plants and animals, it has been stated that an internal stomach, and the chemical principle called nitrogen or

azote, are found in animals only; but this is incorrect,—since the sponge has

plants not only grow and live, but feel, as in the instance of the *mimosa*, or sensitive plant, which closes its rows of leaves on a slight shock, or the *Dionaea muscipula*, Venus' fly-trap (Fig. 1), the leaf of which folds up and incloses any unhappy fly which may alight upon the three hairs (A). The disposition of most flowers to seek or shun the sunlight, and of the ears of corn in the growing corn-field to droop when the sun has set, might be adduced as instances in proof of the sensibility, apart from the mere vitality, of plants. But in addition to this, it is well known that the spores, or undeveloped young plants of *Confervæ* and of sea-weeds (Fig. 2) move about by the action of their own cilia or hairs, until they have found a resting-place to which to attach themselves.

Thus we may add a degree of locomotion to the qualities of plants, and say that, in some instances, they grow,

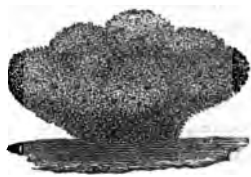


Fig. 3.—SPONGE.

The sponge as it is found growing and attached to a rock.

no internal stomach, and nitrogen is present in the seeds of almost all plants. More recently, it has been averred that the presence of a secretion, or product known as starch (Fig. 4), would clearly establish the existence of vegetables; but recent microscopic researches have shown that starch is also met with in the lower classes of animals,

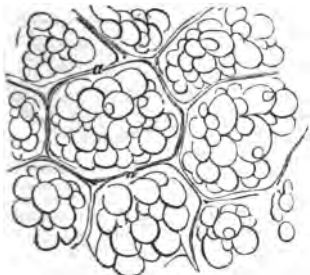


Fig. 4.—Section of a potato, showing the grains of starch inclosed within cells.

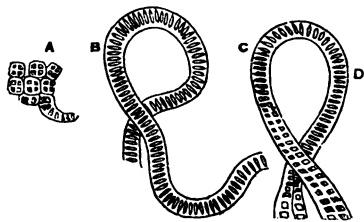


Fig. 5.—Varieties of DESMIDIACEÆ, or SEA-WEEDS.

A, clusters of *Protococcus viridis*.

B, filament of *Schizogonium murale*.

C, a similar filament, subdividing laterally at D.

and in the brain and spinal cord of the higher animals, and even of man himself. Lastly, certain of the *Algae*, or sea-weeds, as the *Desmidiaceæ* and *Diatomaceæ* (Fig. 5), are still claimed equally by the botanist and the zoologist.

Thus simple as at first sight it might seem to state what a plant is as distinguished from an animal, we find it impossible to distinguish the lowest plant from the lowest animal; and have therefore no alternative than to say that we cannot give an unimpeachable definition of a plant.

Definition of the Subject.—We shall assume that our readers can recognise a plant, although we cannot define it, and proceed to a description of those various parts of which a plant is composed, and of the arrangement of plants into classes. These two branches of the subject—*viz.*, structure and classification—have a necessary dependence upon each other; for the idea of classification implies that certain members have some properties or parts in common—such, for instance, as the leaf or flower; or in other words, that their structure corresponds. Therefore a knowledge of structure is essential to classification; and before we describe the latter, we must indicate the internal and external parts of which plants are composed.

ANATOMY OR STRUCTURE OF PLANTS.

Elementary Tissues.—In proceeding to a consideration of the anatomy of plants, it will be evident that, as plants in general have external organs, as leaves and flowers, so must they have more minute parts of which these organs are composed. These will correspond with the flesh and bones of the various parts of our body, and are termed “elementary tissues.” We shall take them first in order, since they are formed before the organs can be developed. They will also furnish us with drawings of some of the most exquisitely-minute beauties of nature.

Formative Fluid.—But as the formation of a leaf, for example, implies the previous existence of elementary tissues, so does the presence of an elementary tissue imply the production of a material fluid, out of which the elementary structure was formed. This latter is called the “formative fluid,” or “organic mucus,” or “cambium,” or “organizable matter” (all of which terms have the same original signification), and is the sole source of production of every tissue found in plants. It is, in this respect,

similar to the blood of animals; for that fluid is the source of all the solid parts of the body. It is semi-transparent and semi-fluid in the internal parts of many plants, and of young plants, and those with thick leaves, more particularly. In this condition it is also found in great abundance between the bark and the wood of all trees in the early spring months; and then separates those parts (A, Fig. 6), so as to permit the bundles of young wood to pass down from the leaves, and thus enable the tree to grow. It is under these circumstances that the woodman strips the bark from trees which are to be cut down, since then it does not adhere to the wood. The fluid is termed *cambium* in this situation. When this formative fluid is met with in the external parts of plants, it is still semi-transparent; but it is then solid, as may be observed by scraping the surface of a box-leaf.

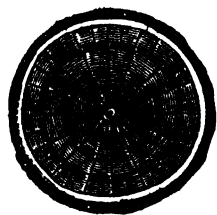


Fig. 6.—Section of the stem of a tree, the white line showing the colourless cambium, or formative fluid, deposited between the bark and the wood in the early spring.

Elementary Membrane.—The first step in the formation of any tissue from this formative fluid is the production of a solid structureless fabric, called elementary membrane, and a modification of that fabric termed elementary fibre. It will be observed that these elementary parts are structureless, and are produced, apparently, by inspissation or thickening of the formative fluid. The process may be grossly illustrated by a reference to the manufacture of paper, in which the rag-pulp (*vis.*, rags torn into threads and soaked in water) corresponds to the formative fluid, and the paper, which is subsequently produced, to the elementary membrane. The paper thus obtained is fitted for the manufacture of books, and other articles; and, in like manner, the elementary membrane is the solid material out of which vegetable tissues are formed.

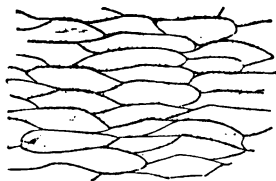


Fig. 7.—Cells of EPIDERMIS, from the seed of the Gourd.

drops, with spaces between them; and that when a fluid is inspissated the drops are brought closer together. Thus, whilst evident openings are not naturally met with in membrane, except as shown by Professor Quekett, in the leaves of a moss called *sphagnum* (Fig. 8), it must be highly though invisibly porous, and permit certain fluids to filter through it.

It is at first thin and translucent, as may be seen in the membrane covering the seed of the gourd (Fig. 7); but in many cases it subsequently becomes thicker and more opaque. In the structures of the ferns (*filices*) it assumes a decidedly brown colour; and in the claters of

Elementary membrane, then, as in Fig. 7, is structureless; but, theoretically, it is assumed to consist of a layer of rounded particles, which lie side by side, and leave most minute spaces between them. This must be so, when we reflect that all fluids, including the formative fluid, are made up of rounded

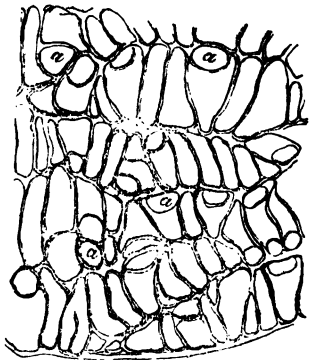


Fig. 8.—Leaf of the SPHAGNUM, showing at a the natural openings through the tissue.

the *Jungermannia*, a kind of moss (Fig. 10), it is of a beautiful red colour; these variations,

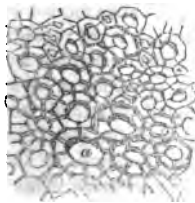


Fig. 9. — Thick walled cells of the *Pinus Webbiana*, showing the amount of deposit between the cavity and the outer cell wall.

and especially in thickness, result from the altered duties which it is required to perform. Thus, in the structure of bark and fruits, it is not merely thickened, but is lined by a deposit of hard sedimentary matter, of great power of resistance, in order to increase its strength and to resist decomposition. This hardened tissue is called *sclerogen*, or *hard tissue* (Fig. 9).

In less extreme cases the deposit is in much smaller quantity, and appears only as minute grains scattered over the surface. Such is the case in the pith of the elder (*Sambucus niger*—Fig. 11). A yet more interesting instance of this scattered mode of deposit is

found in the hairs of the fornix (a part of the flower) of the *Anchusa italica* (Fig. 12). These are covered with a series of tubercles, which are nothing more than isolated masses of a new deposit. In other instances still, the thickening of the membrane appears to have been produced by a deposit of the ordinary transparent organic mucus of which it was originally composed, and still remains transparent, and beyond this differs only from ordinary membrane in that this new matter is laid on unequally, and certain transparent spaces are found where the deposit has not taken place. These spots are oftentimes



Fig. 10.—Fibres of the *Jungermannia* crossing each other spirally, and, in their natural state, of a red colour.

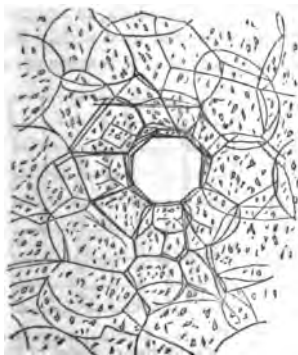


Fig. 11.—Pith of the ELDER (*Sambucus niger*), showing the dotted tissue.



Fig. 12.—Tubercles on the hair of the fornix of the *Anchusa Italica*.



Fig. 13.—Section of the stem of the VINE (*Vitis Vinifera*), showing the vacuic spaces or dotted tissue

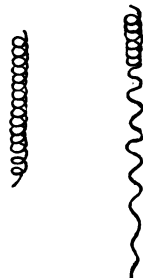


Fig. 14.—Elementary fibre free from membrane.

with great regularity, and sometimes in a spiral manner; so that the tissue becomes one of the most beautiful of vegetable microscopic objects. Such tissue is termed "*dotted*" tissue, and is found in most plants, but more particularly in the common cane (*Rattan*), and the vine (*Vitis vinifera*—Fig. 13). The use of this tissue is not well known.

Elementary Fibre (Fig. 14) is not formed from membrane, as though the latter

were cut up or drawn out into threads of almost inconceivable fineness, and therefore a production of membrane; but both it and the elementary membrane are alike formed out of the formative fluid. Moreover, it is not regarded as a substance separate from membrane, but as a deposit upon one side of a pre-existent membrane. Whenever it is found detached from membrane, we must assume that the membrane which supported it has been removed, or that it has detached itself from the membrane. This is admirably shown in Fig. 15, in which the fibre is in process of being denuded by the destruction of the membrane. It is usually, perhaps invariably, solid, and commonly has a rounded figure. It is also transparent, except in a few cases, as in those of the *Jungermannia* before referred to, (Fig. 10.) Its use is clearly that of supporting the more extended membrane, and of preventing any folds of it from approximating too closely to each other.

Fig. 15.—Tube from the *RICINUS COMMUNIS*, or castor-oil plant, showing the fibre at *a*, and the edge of the broken enclosing membrane at *b*. Magnified 200 diameters.*

Cellular Tissue, or Parenchyma.—Having now considered the “raw material” we may proceed to describe the structures which are produced from it. These structures are very varied in appearance, and are ultimately applied to very varied purposes; but yet, in accordance with the simplicity which marks all the works of God, all this may be reduced to one tissue, a structure which, in addition to its being the fundamental tissue, is, in its own proper form, the most widely distributed of all tissues. This is termed Cellular tissue, to signify that it is made up of

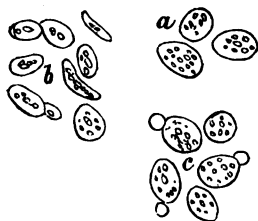


Fig. 16.—Detached Cells.
a, cells of the yeast plant (*Torula cerevisiae*) with their granular contents.
b, the same cells in process of forming new cells, as seen by the bulgings.
c, similar cells of the sugar plant found in the urine in diabetes.



Fig. 17.—Cells with only two attachments.

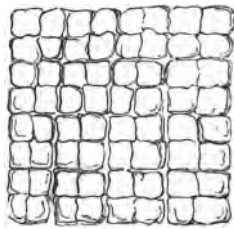


Fig. 18.—SARCINA, magnified 800 diameters, found in the stomach in states of disease. It is a vegetable of low organization, and resembles somewhat the ornament formerly worn on the breast of the Jewish high-priest. It consists of a mass of cells.

hollow cases or cells. It is, moreover, that tissue which is the first found in all plants.

* This and a large portion of the subsequent drawings have been made from original specimens. Others have been derived from various sources, and more particularly from the excellent lectures of Professor Quekett, delivered at the Royal College of Surgeons.

The cells of which it is composed may be either detached wholly or partially (Fig. 16), or be more or less conjoined in masses, (Figs. 17 and 18). Their characters are of course the best seen when they are detached from each other.

The only difficulty, if any, in reference to tissue is in obtaining a correct idea of the simplest of all structures—the cell. This may be likened to an orange (Fig. 19), when the rind, *a*, will correspond to the cell-wall, or boundary of the cell, and the juicy part, *b*, will represent the contents of the cell. Thus an orange is a cell on a large scale. Or it may be compared to a fowl's egg, when the shell will represent the cell-wall, and the white, with the yolk, the contents of the cell. The egg, therefore, and all similar inclosed bodies, are magnified cells. But the egg has other points of resemblance to the cell. Thus, if the white of the egg be drawn from the shell through a small hole, so that the latter shall remain empty (a process very familiar to school-boys), we may form a just estimate of the cell-wall as separate from its contents. A cell in botany, therefore, consists of a cell-wall and contents, although it be so small as to be undiscernible by the unaided sight.

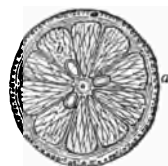


Fig. 19.—ORANGE.
a, the cell-wall.
b, the contents of the cell.

We have already stated that cellular tissue is formed from elementary membrane; and therefore the cell-wall is nothing more than elementary membrane folded, with the edges adherent together, so as to be able to inclose the contents.

The contents of cells are, however, of another nature, and are not produced from elementary membrane. They are of three kinds. 1st, a substance lining the inner

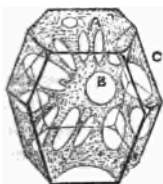


Fig. 20.—Cell after Unger. The outlines, *C*, are intended to represent the boundary of the cell, or the cell-wall. *B* is the central nucleus or cytoblast. *A*, the lining of the cell-wall or the primordial utricle of Mohl.

side of the cell-wall, as illustrated by the white of egg, and called the primordial utricle of Mohl. It is well shown by the shading in Fig. 20, *A*. This substance is of exceeding importance in the development and growth of the cell, and in the production of its other contents. 2nd, a roundish, tolerably-large body, or nucleus, or cytoblast, represented in Fig. 21, *b*, met with in various parts of the cell, but usually near to some part of the cell-wall. This may be likened to the yolk of the egg, and bears the like degree of importance to the other parts of the cell that the yolk bears to the egg. 3rd, certain lesser bodies varying in size, shape, and number, termed

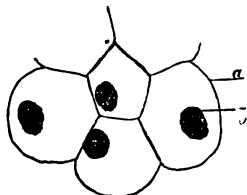


Fig. 21.—Cells from the flowering stem of the leek (*Allium Porrum*), showing at *a* the cell-wall, and at *b* the nucleus and the nucleoli. The other contents of the cell are transparent.

nucleoli, formed within the nucleus.

It appears that the nucleus is a central point of all actions proceeding within the cell, but that the primordial utricle is the efficient agent. All these parts may be familiarly and readily observed in the common strawberry (*Fragaria*), or the mistletoe berry (*Viscum album*), or any other juicy fruit. We assume that our readers have a small microscope of some kind, which may be obtained for a sum varying from £2 to £4 of any respectable optician, with pieces of glass and other apparatus needful for microscopic observation. Take then, with the point of a needle, a piece from the centre of the strawberry, not larger than a pin's head; place it in the glass slide,

and add a drop of water.

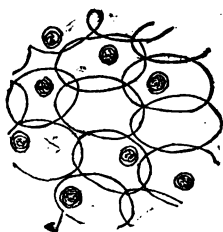


Fig. 22.—Cells from the Strawberry, showing their oval shape, loose connexion, large nucleus, and translucent walls.

Pull it to pieces by the help of two needles, and then cover it with thin glass, and place it under the microscope. It will be found to consist of a mass of large cells (Fig. 22), with transparent walls, and a slightly coloured fluid, inclosing the large rounded nucleus. It is of importance to obtain clear notions of a cell, since it is the foundation of all other tissues, and since it contains the starch and all other secretions of plants.

The figure of the cell is unimportant, and varies very greatly. It is believed to be generally accidental, as the phrase is,—the accident being that of pressure: not that by the term “accident” is meant that the figure is a matter of chance; for in certain parts of plants, as in the pith, for example, the figure, whatever it may be, is always the same. If pressure, therefore, in such cases be the efficient

cause, it is exerted in determinate degrees and directions in the various parts of plants. When the schoolboy blows bubbles of soap-and-water he makes rounded cells, because the walls are of equal weight, and the pressure of the air of an even degree all round. If, however, a drop of water be attached to the bubble it will destroy its rounded form, and elongate it in the direction of the earth, rendering the cell more or less oval. But if the same soap-and-water be well shaken in a half-filled bottle, the unequal pressure will drive the cells together, and render them distinctly six-sided.

This little experiment will convince the reader that the figure of the cell does, in a great degree, depend upon pressure, and that it may be altered as the direction or degree of pressure is changed.

So also in plants when each cell is detached from every other, as in decomposing vegetable infusions; or as in the yeast plant (*Torula Cerevisiae*—Fig. 16), the form is spherical or ovoid; when it lies loosely in juicy fruits, as in the strawberry (*Fragaria*—Fig. 22), it is large and nearly round; when two or more cells are attached end to end, as in the mushroom (Fig. 23), they are ovoid or elongated; and when they are numerous and inclosed in a common skin or bark, they become more or less six-sided, as in the pulp of the orange (*Citrus*), from mutual and surrounding pressure (Fig. 24). It will then be readily understood that the figures of cells may be innumerable; but experience has shown that hexagonal and octagonal forms are those which most abound. These are the forms observed almost universally in pith, cuticle, leaves, flowers, and fruit; but it should be remembered that regularity of outline, although of common occurrence, is by no means essential.

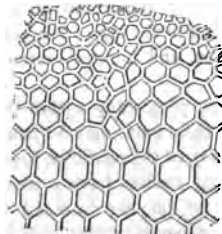


Fig. 24.—Hexagonal cells.

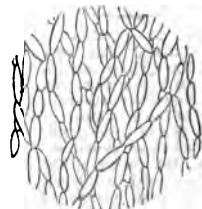


Fig. 23.—Ovoid cells of the mushroom, attached end to end.

But, whilst it must be admitted that the figure, in most instances, results from pressure, in other instances it proceeds from a more determinate source; viz., the direction of the growing process. This is readily understood, if we imagine a spherical cell in which the growing process is not equally carried on all over it, so that it may continue to grow spherical; but whilst the process is arrested at one point it proceeds

at an opposite one. This will terminate in an elongated cell, such as those observed in

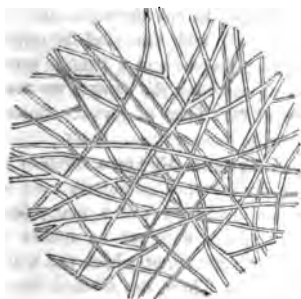


Fig. 25.—Elongated cells of a mushroom (*Boletus*) resembling tubes.

the mushrooms (*Fungi*—Fig. 23), and more particularly in a gigantic kind of mushroom termed the *Boletus* (Fig. 25), in which the length of the cell exceeds the breadth by many diameters. In this mode it is conceivable that a tube might be formed from a single cell, or from a series of cells, if placed end to end, and the partitions broken down, although no satisfactory



Fig. 26.—Diagram showing a series of cells which, by the breaking up of their partition walls, are forming a tube.

illustration of this mode of conversion of cells into tubes has yet been discovered (Fig. 26).

The terms, oblong, lobed, square (Fig. 27), muriform (Fig. 28), prismatic, cylindrical, compressed, sinuous (Fig. 30), and stellated, have, amongst others, been devised to indicate other forms of cells than those above indicated.



Fig. 27.—Cubical or square cells.

The cell varies as greatly in size as its figure; so that, on the one hand, they may be seen by the naked eye, as in the pulp of orange, lemon, or shaddock; on the other they are so minute that it is necessary to examine them with a high magnifying power.

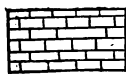


Fig. 28.—Muriform cells, or cells resembling the bricks in a wall.

The limits of variation are $\frac{1}{10}$ and $\frac{1}{1000}$ parts of an inch in diameter.

Some form of cellular tissue constitutes the whole of most of the lower classes of plants, as the *Fungi*; and in all other plants it is found in the roots, or subterranean stems

(as the potato, radish, and turnip); in bark, pith, leaves, flowers, seeds, and fruit. The cuticle of leaves, in general, is furnished with cells, having a sinuous or wavy outline, thence termed the sinuous variety (Fig. 29).

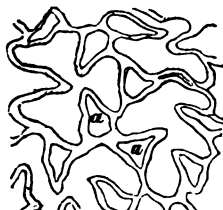


Fig. 29.—Very irregular stellate cells from the foot-stalk of a leaf of the sweet-burr reed (*Sparganium ramosum*), showing the lacunae, or inter-spaces at *a*, bounded by the cell walls.

The most interesting variety of cell is that termed stellate, or star-like, from the radiating form which it assumes. This is well seen in the rush (Fig. 30), in the sweet-burr reed (*Sparganium ramosum*—Fig. 29), in the yellow water-lily (*Nuphar lutea*), and in many other

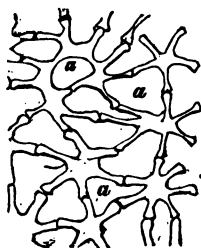


Fig. 30.—Star-shaped cells of regular character, from the stem of a rush, having lacunae at *a*, bounded by cell-walls, and the union of the cells indicated by the transverse line at the middle of each arm or ray.

water-plants of loose tissue. We have also met with a beautiful illustration of it in the partitions of the cells constituting the thick central parts of the long leaves of the Banana tree (*Musa paradisiaca*). The construction of this

from of tissue is simple, and results from a puckering inwards of the cell-wall towards the centre. If an orange be cut through, and the contents partly removed, and the rind be then pressed by two or three fingers and a thumb until the projected portions approach the centre, we may form a correct idea of this form of tissue. Something more, however, is necessary.

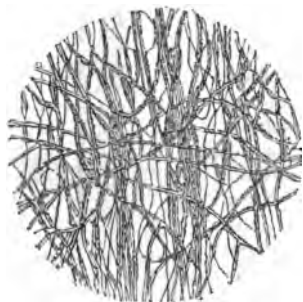


Fig. 31.—The fibrous structure of the fowl's egg-shell, almost exactly simulating the cells of the *Boletus* (Fig. 25).

other for some distance, they constitute inter-cellular passages, and are very abundant in all aquatic plants. The relation which the inter-cellular spaces bear to the stellate cells is this, that when the cell-wall is pressed inwards, in various directions,

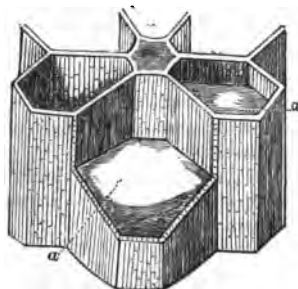


Fig. 33.—Air-chambers of an aquatic plant—the *LIMNOCHARIS PLUMIERI*, exhibiting extreme regularity of form.

towards the centre of the cell, the cell seems to be reduced to a series of arms (Fig. 30), whilst the spaces between the cells now appear to be a series of cells themselves (Fig. 32). These enlarged inter-cellular spaces are termed *lacunæ*.

Inter-cellular Spaces.—When a number of cells are pressed closely together, so closely even as to cause them to assume the form of a many (say twelve) sided figure, there will yet be spaces of triangular shape at each corner, at which the walls do not absolutely touch. These are termed inter-cellular spaces, and are the larger by so much as the cells are not closely applied to each other. When these inter-cellular spaces are placed one over the

others, they constitute inter-cellular passages, and are very abundant in all aquatic plants. The relation which the inter-cellular spaces bear to the stellate cells is this, that when the cell-wall is pressed inwards, in various directions, towards the centre of the cell, the cell seems to be reduced to a series of arms (Fig. 30), whilst the spaces between the cells now appear to be a series of cells themselves (Fig. 32). These enlarged inter-cellular spaces are termed *lacunæ*.

The uses of the inter-cellular spaces and passages are of great importance, since, in aquatic plants (in which they chiefly abound), they contain the air which imparts buoyancy, and retains it on the surface. This fact may, in some degree, account for the great size of these spaces in many aquatic plants (Fig. 33). In other plants, their use is chiefly that of a depository of secretions.

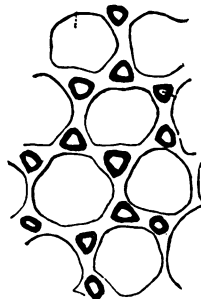


Fig. 32.—VARIEGATED *CORNUS MASCULÆ*, showing the formation of inter-cellular spaces in disease.

Before concluding our account of cells we must briefly refer to some modifications.

The **DOTTED CELL** differs from the ordinary cell only in having been constructed from dotted membrane in place of plain. This form is very abundant, and especially in the stem of the vine (Fig. 13) and other fast-growing plants, in the bark of most wooded trees, and in the roots of many plants, as of the common horse-radish. They are usually of large size.

Thick-walled Cells, or Sclerogen, are the result of the deposit of the peculiarly hard tissue termed sclerogen, on the inner side of the cell-wall. This substance is usually found deposited in concentric layers (Fig. 34), so that at length

the cavity of the cell is nearly filled. There is, however, always a central vacuity, and this is in direct connexion with the cell-wall by a series of canals, which pass through the various layers of hard tissue. This is absolutely necessary, since all actions proceeding in the cell must require the direct communication of the cell-wall.

The thick-walled cells constitute the gritty tissue of the pear (Fig. 35) — a tissue found in the form of small hard grains near to the centre of the fruit. It is also abundant in the so-called bulbs of many orchids, as the *Marchantia polymorpha*; on the covering of the seeds of many plants, as of the star-anise (*Illicium anisatum* — Fig. 34), and the apple (*malus* — Fig. 36); in the strong part of many nuts, as of the ivory nut (Figs. 37, 38), now so usefully supplying the place of ivory; in the common hawthorn (*Crategus*), plum, and our garden

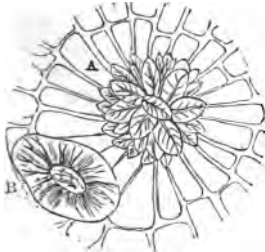


Fig. 35.

A, a mass of thick wall-cells from the PEAR, known as the gritty tissue.
B, a cell more highly magnified.



Fig. 36.—Sclerogen immediately inclosing the seed of the apple.

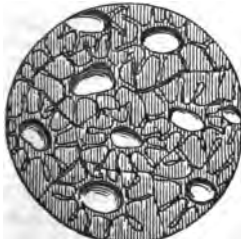


Fig. 38.—Transverse section of thick wall-cells of the Ivory Nut. (*Phytelphus macrocarpa*).

balsam. If the section is too thick it must be ground down on a whetstone, in the



Fig. 34.—Beautiful thick wall-cells from the seed of the *Illicium anisatum*, or star-anise, showing the concentric layers, central cavity, and radii.

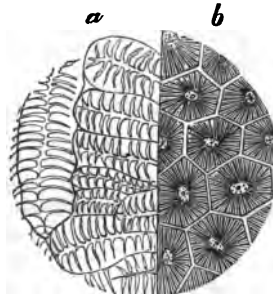


Fig. 37.

b, perpendicular section of the bark of the Ivory Nut (*Phytelphus macrocarpa*).
a, longitudinal section.
Both show the lines of communication between the centre and the circumference.



Fig. 39.—Thick wall-cells from the Cocoa Nut shell, with their central cavities and communicating tubes.

manner in which sections of bone are prepared for examination. It is impossible to examine these interesting structures, and to observe how admirably they are adapted to give strength and power of resistance to parts which pre-eminently require it, without being reminded of the great similarity between them and bone cells in the bones of animals. There are, however, several points of dissimilarity; and, amongst others, that the cell-wall, which is retained in thick-walled cells, is lost in bone cells.

Fibro Cellular Tissue.—This form of cell is marked by having one or more fibres wound in a spiral direction on its inner side (Figs. 41 & 43). The fibre may be loose in the cell, as in the *Opuntia vulgaris* (Fig. 42), where it is flat, or in the elongated cell of the hairs on the seed of the *Collomia grandiflora*, or of the common sage, where it is round.



Fig. 41.—Fibre cell from the leaf of the *PLEUROTHALLIS*, having a single fibre.

whilst the other part of the fibre is attached to the membrane. In this mode the resistance is unequal, and a circular or spiral direction is given to the new structure. This form of cell is very abundant, and is probably more or less filled with air, since the inclosed fibre is well fitted to prevent the collapse of the two sides of the cell.



Fig. 42.—Fibre cell from the *OPUNTIA VULGARIS*, showing a flattened fibre lying detached from the cell-wall.

It is usual to find the cells not isolated, but in clusters, and oftentimes arranged in masses with much symmetry, as may be seen in the drawing (Fig. 44) of the fibro-cellular tissue lying *in situ* in the leaf of the *Pleurothallis*.

There is no structure in animals corresponding with the fibro-cellular tissue in vegetables; but cellular tissue in the simple form is exceedingly abundant, and, in the form of fat cells (Fig. 45), bears great resemblance to cells of vegetable origin. It is also an interesting fact that the cartilage of the ear of the rat and mouse (Fig. 46), and more particularly of the rudimentary spinal column of the lamprey, is so modified as almost exactly to simulate a vegetable cell.



Fig. 40.—Concentric layers of Sclerogen in old cells of the bark of the *BEECH TREE* (*Fagus*).



Fig. 43.—Fibre cell from the leaf of an *OACIS* (*Saccolobium guttatum*), having several fibres wound in opposite directions.

This resemblance between animal and vegetable structures is equally well seen in

the tissue of the egg-shell (Fig. 31), when contrasted with the elongated cells of the *Bolus* (Fig. 25).

It is an evidence of the power and wisdom of the Deity that all the tissues, both in

animals and plants, are produced from one simple structure—the fundamental cell.

The uses of the cellular tissue are :—

1st. To contain various important secretions, as that of starch, and the organs of reproduction in all classes of plants.

2nd. To carry on the circulation more or less in all plants, but more particularly in those which consist only of this tissue. This is well exemplified in the leaf of the *Vallisneria* (Fig. 47), in which the circulation may be seen proceeding under the

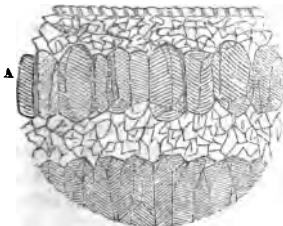


Fig. 44.—Cells of fibro-cellular tissue in situ, A, in the leaf of an *ORCHIS*, the *Pleurothallis ruscifolia*.

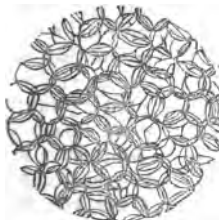


Fig. 46.—Cartilage from the ear of the rat, closely resembling loose cellular tissue in vegetables.

microscope.

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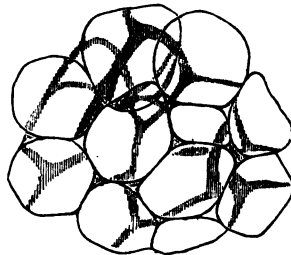


Fig. 45.—Fat cells in animals.

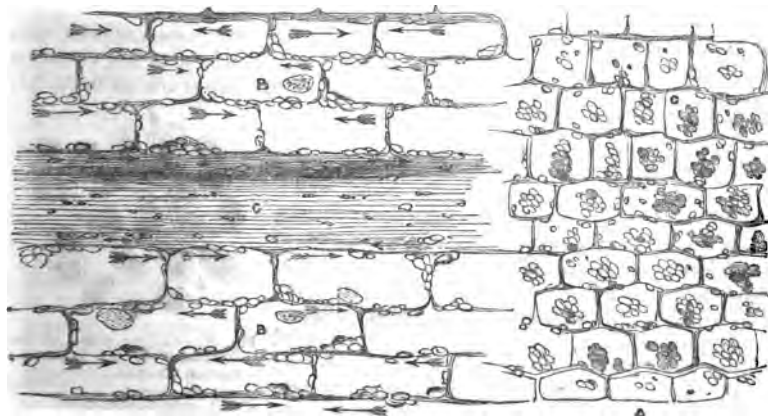


Fig. 47.—Leaf of an aquatic plant, the *VALLISNERIA SPIRALIS*, showing the circulation in plants. 1 represents the leaf after the upper surface has been sliced off, and shows at B the cellular tissue, with small rounded grains, chiefly composed of starch, and a larger detached body—the nucleus. The portion at C is a bundle of woody fibre, in which the circulation is also proceeding. The circulation proceeds around each cell separately, and the arrows indicate its direction along the bottom of each cell. 2 has been drawn from the surface of the leaf, and shows a number of starch granules in cells chiefly aggregated together, and which do not circulate. Magnified two hundred diameters.

3rd. By the tenacity of its structure, and the looseness of its parts, to bind the component parts of the plant together, and to increase its elasticity.

4th. It has for thousands of years been of great use to man for various economic purposes :—

First, in the form of *papyrus*, or the paper derived from the stem of a rush of that name, and employed as such by the ancient Egyptians, Grecians, and Romans, until long after the birth of Christ. In a similar way it is still used by the Chinese, and by them is derived from the pith of a plant (*Eschynomene*—Fig. 48), which they cut into very thin slices. This material lends a charm to Chinese drawings, since its cellular character enables it to absorb the colouring materials in great abundance.



Fig. 48.—Section of the Chinese rice-paper, or *Eschynomene*, showing large cells with a scattered deposit.

Secondly, as a textile fabric. The mummy-cloths of the Peruvians, who existed long before the era of Montezuma and the Spanish invasion, are composed of this tissue only. At the present time we obtain cotton (Fig. 62 B) chiefly from America, where it is derived from the seeds of the cotton plant (*Gossypium*). It is far less resisting and durable than woody fibre or linen; but its comparative abundance, low price, and easy working have obtained for it great favour. The present war with Russia will probably induce a determination to use the cotton cell to the still greater exclusion of the woody fibre; and it has recently been shown in America that ropes made of cotton are far stronger and more durable than has hitherto been believed.

Paper is made from the manufactured cotton, and also from the refuse part of the raw material.

Multiplication of Cells.—It is not within the limits of this essay to enter upon the interesting question of the production of cells; but we may state that a common mode is that of division of the cell into two or more cells. This is effected in the following manner :—First, there is an aggregation of the contents of the cell around the nucleus, whilst the nucleus manifests a disposition to divide itself into two by a line of constriction on either side. Secondly, the cell-wall is bent inwards towards the point of division of the nucleus, and by degrees insinuates itself between the two parts of the nucleus as the division of the latter proceeds, until at length the cell-walls from opposite sides meet at the centre of the nucleus, and the nucleus is divided, and two cells produced. Each of the new cells contains half the original nucleus, which now constitutes the nucleus of each cell; and after a period it is prepared to subdivide and to form another cell, and thus progressively, so long as the vital process lasts. In this way it is conceivable that an immense multitude of cells may be produced; and should the division be speedily effected, we may form a conception of the astounding fact, that in some of the fast-growing cellular plants—as the mushroom—the cells have been produced at the rate of sixty-six millions in a minute.

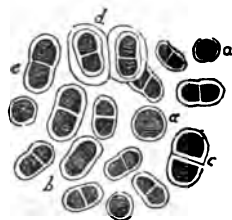


Fig. 49.—Various stages of development of the *HEMATOCOCCUS BINALIS*.

- a, the simple cell.
- b, the cell preparing to divide.
- c, the cell divided, and a new cell thus produced.
- d, a divided cell again repeating the process of subdivision.

It is proper to state further, that certain authorities attribute the production of cells to the evolution of bubbles of gas in an azotized fluid, and they are of opinion that only by that mode can we account for the extreme rapidity with which cells are developed.

Bothrenchym, or Pitted Tissue.—We now proceed to describe the various modifications of the fundamental cellular tissue, and first, that of Bothrenchym, since it is very nearly allied to cellular tissue. It is so called from two Greek words signifying pitted tissue, to indicate that a number of translucent spots are distributed over its surface. We have already described the mode of formation of this tissue when considering dotted cells, p. 7. It differs from dotted cells chiefly in size; for it may be regarded as a series of very large cells, placed end to end, and separated from each other by obliquely-placed partitions. At a later period of life it puts on the character of a tube by the breaking-up and removal of the partitions. Its ordinary position in plants is in the stems of wooded plants, and more particularly of such as attach themselves to other trees for support, and grow rapidly. Thus it is met with on a thin longitudinal section of almost all trees, but more readily in the alder (Fig. 50), vine, clematis, cane (*Rattan*), and similar fast-growing plants, and wherever a rapid circulation is proceeding. In this respect it differs from mere dotted cellular tissue, since that is more commonly found in the herbaceous than wooded plants. This, in common with other vegetable tissues, retains its characters perfectly for thousands of



Fig. 50.—Section of the root of the ALDER TREE (*Alnus*), showing the large-sized pores, or semi-transparent spaces, of its pitted tissue.

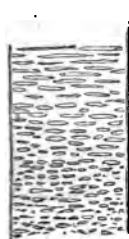


Fig. 51.—Porous duct, from Anthracite coal.

years, as may be observed in the annexed figure of a duct (Fig. 51), taken from a piece of anthracite coal.

It is not uncommon to find a spiral fibre associated with the dotted tissue, as in Fig. 52, when the tissue may be regarded as a spiral duct with pores. It is a microscopic object of much interest, and very easily obtained. Take a piece of common cane, and having cut away a portion of the outside, take a thin section down the cane, and place it under the microscope in a drop of water. The little pits will be seen with much ease, as also the large size of the tissue as compared with the woody tissue which accompanies it. We have found the best illustration of it in a piece of deeply-coloured rose-wood, for there the dark tint of the secretion gave a peculiar



Fig. 52.—Pores, and a spiral fibre, from the ELM TREE (*Ulmus*).

distinctness to the tissue. Its chief use in plants is to carry on the circulation with great rapidity, and is therefore particularly necessary in such plants as grow in southern and eastern climes, and yield refreshing juices, as, for example, the *vegetable fountains* of India. The importance of this tissue to all plants may be inferred from the large amount of vapour which they throw off by perspiration. Thus an ordinary-sized cabbage, in our climate, was found to perspire to the extent of 1 lb. 9 oz., and a sunflower to that of 1 lb. 14 oz. in a day of twelve hours; and it is evident that the great heat of southern climes must induce a far greater amount of perspiration, and, by consequence, require a more active circulation. The fluid thus exhaled is supplied chiefly by the bothrenchym, which therefore has a circulation proceeding from the roots towards the leaves of the plant. This function is not

seriously if at all impeded by the partitions which lie across the tube, as would at first sight appear; for even should such partitions be perfect, they readily permit the proper fluid to filter through them. The great size of this kind of tissue, and the large quantity of fluid which it contains, render it imperative that it should be supported by structures more resisting than its own. For this reason it is always found surrounded by bundles of strong woody tissue. Another function assigned to it in later life is that of conveying air into the interior of the plant. This occurs when the walls of the cell or tube have become imperfect, and would permit contained fluid to pass out of them; and then the fluid disappears, and its place is supplied by air. A third, and not less important duty, is that of a depository of the secretions of the plant. This only occurs when the tree is mature, and the central parts of the trunk, which are not then devoted to the rapid conveyance of fluid for the purposes of perspiration. The deep-colouring matter of rose-wood and mahogany, and all similar trees, is chiefly found in this tissue.

From the above remarks it will be evident that bothrenchym is a tissue of great interest and importance, and is seen in its integrity only in the early life of a plant. Its large size, thin walls, and active functions, seem to predispose it to injury; and therefore such tubes have the duty assigned to them of conveying air, or of storing up secretions which do not circulate.

Gridiron Tissue.—Under the term of gridiron tissue, Professor Quekett has described an interesting structure, oftentimes met with at the end of the ducts of pitted tissue. It consists of a series of bars which pass transversely across the tube, and occupy the position of the usual transverse septum. It is probably not a distinct structure, but only the remains of the original septum. We have met with fine examples of it in several trees, but more particularly in the alder and white birch (*Betula alba*). A similar condition has also been observed in a fossil palm found at St. Vincent's.

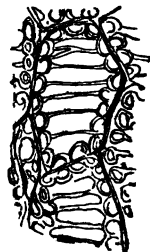


Fig. 53.—GRIDIRON Tissue, forming the termination of a dotted duct in the alder (*Alnus*).

Pleurenychym, or Woody Tissue.—The tissue most closely allied to bothrenchym, and yet widely removed from both it and cellular tissue, is pleurenychym, or woody tissue. This constitutes the mass of the stems of our forest trees, and is thus of the utmost social use to man. It is, also, found in all young and tender shoots, and in bundles in the stems of all, even the most delicate flowering plants. Its peculiar characteristic is that of great tenacity and power of resistance, and for this its structure is admirably adapted. As these characters are opposed to those of bothrenchym, we are prepared to find a tissue differing widely from that large and wide structure. The contrary is found in woody tissue, for it consists of bundles of very narrow fibres, with tapering extremities, and so placed end to end that the pointed ends overlap each other. Each fibre is very short, and the partitions which result from the apposition of the fibres, end to end, do not interfere with the circulation through them. Moreover, the tube is not composed of simple thin membrane only; but, in addition, has a deposit within it, which, without filling the tube, adds very greatly to the strength of the fibre. Perhaps we have here as good an illustration of the wisdom and power of the Creator as can readily be produced—viz., an arrangement whereby the greatest strength and power of resistance and elasticity shall be obtained, and at the same time the functions of circulation uninterruptedly maintained. The strength is mainly due to the shortness of each fibre, the connexion by apposite ends of many fibres almost in one direct line,

from the root upwards; and, lastly, to the deposit on the inner side of the membrane. This sentiment is irresistible, when we remember the various economic purposes

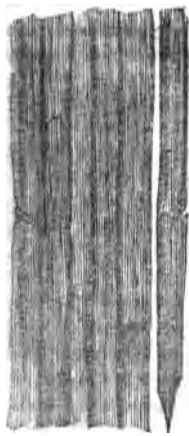


Fig. 54.—Bundles of woody fibre of the flax plant (*Linum*), considerably magnified.

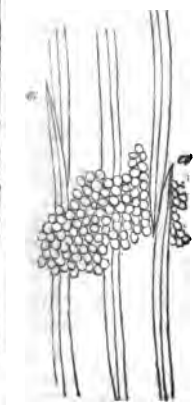


Fig. 55.—Several woody fibres with internal deposit and their pointed extremities overlapping each other.

to which man in all ages has applied the wood of forest trees, and also the power of resistance and elasticity which trees are required to offer while supporting large branches at a considerable angle, and to prevent their being uprooted or broken to pieces by violent storms, all of which is mainly due to the tissue now under consideration.

There are two kinds of woody tissue—*viz.*, the plain and the glandular. The plain we have already described. The glandular is that form which more nearly resembles bothrenchym, and indeed may easily be mistaken for it. It consists of a plain fibre or tube, such as that already described; but, in addition, there is superimposed, with great regularity, a series of rounded translucent bodies called, or rather mis-called, glands (Fig. 56). These are, for the most part, arranged in single rows, and are so large as to occupy the whole face

of the fibre.

There is great difference of opinion as to the nature of these so-called glands; some authors regarding them as simple concavities in the nature of a simple pit, whilst others believe that there is a pit, and in that pit is deposited the rounded, flattened body termed the gland, or bordered pore.

Professor Quekett adopts the opinion that these bordered pores lie in concavities between two adherent fibres (Fig. 57). The bordered pore is hollow, and biconvex, so as to fit into the two cavities. They are best seen in a section of wood, taken parallel to the medullary rays.

It is not a little remarkable that this form of woody fibre should be found only in one class of trees—*viz.*, the *Coniferae*, or fir tribe, with their allied genera; and in such plants it is the only form of woody tissue met with. If a very thin section of a piece of fresh fir tree, or of a piece of deal or cedar, be examined with the microscope, as before directed, the glands will be seen very distinctly (Fig. 56); and if a piece of rotten fir be selected, it will not be difficult to find a spot at which the gland appears to have fallen out. Such also is the case with the coal shale, a large portion of which is composed of the stems of the fir tribe, which have been buried during thousands of years; and if care be taken to grind down a thin section, not only may the glands and their remains be seen, but in some instances the pits which once contained the gland.

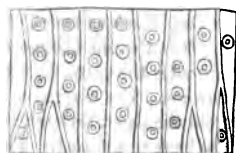


Fig. 56.—Section of common fir wood, or deal; showing the pointed extremities of the woody fibre and the gland, or bordered pores, in a single row on each fibre.

This, however, is chiefly a matter of curiosity, since we do not know anything of

the especial functions of this kind of woody tissue. The botanist, however, attaches value to it, since it enables him to demonstrate, in recent and fossil woods, the existence of the *Coniferae*, or fir tribe of plants.

It is not uncommon to find a spiral fibre associated with this glandular structure, and sometimes, as in the yew (*Taxus baccata*, Fig. 60), there are two which are wound

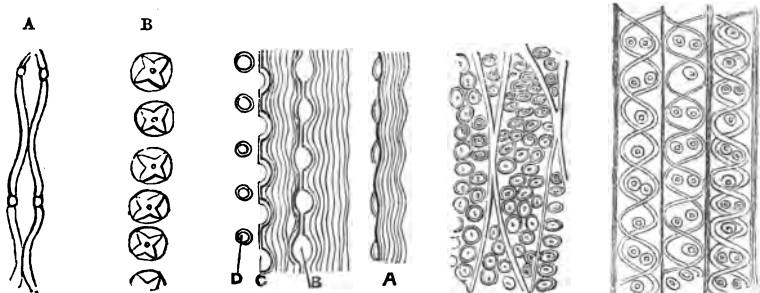


Fig. 57.

Fig. 58.

Fig. 59.

Fig. 60.

Fig. 57. A lateral view of two adjoining fibres to show the concavity in each, and the space formed by both for the reception of the bordered pore. B, bordered pores from the *Salisburia adianthifolia*, which are naturally found in cavities similar to those in A.

Fig. 58. Similar arrangement of tubercles and cavities of the *Aporosa anceps*. A, a fibre with the tubercles or glands *in situ*, and projecting. D, the glands detached. C, the concavities on one fibre whence the glands have been removed. B, the spaces for the lodgment of the glands formed by two adjoining fibres.

Fig. 59. Rows of bordered pores on the woody fibre of a fossil member of the fir tribe, which had been long buried in the State of Ohio.

Fig. 60. Porous woody fibre in the yew (*Taxus baccata*), with the spiral fibres wound in opposed directions.

in opposite directions, and give the appearance of a net-work. This is presumed to assist in maintaining the patency of the trache.

The uses of woody fibre are very varied, and most important, and may be divided into two categories,—1st, such as benefit the plants; and 2nd, such as benefit man.

1st. Such as benefit the plant.

It is the chief organ of the circulation in all wooded plants, and for this purpose pervades the plant from the root to the branches, and even to the minutest leaves and flowers. The current in this tissue is slow and uninterrupted, and is directed upwards from the shoot through the stems to the leaves, and downwards from the leaves through the bark to the root. Thus its current has a twofold direction; the ascending and chief one being for the purpose of taking the raw sap from the ground, to be digested in the leaves, and the descending being devoted to the removal from the leaves of the digested sap, to be applied to the purposes of the plant, and also of the refuse matter to be carried to the roots, and thence thrown out into the soil as a noxious material. These functions are carried on more vigorously during the spring and summer seasons; but it is probable that even in the depths of winter it does not cease.

Another function of woody fibre is to be the store-house of the perfected secretions. It is well known that as trees advance in life, the wood assumes a darker colour, and more particularly that lying near to the centre of the stem. This is due to the deposit of the perfected juices in the woody fibre at that point; and when age has matured the tree, it is probable that the woody fibre so employed is no longer fitted for the circulation of the sap; and also, that the perfected sap, when once deposited, does not again

join in the general circulation. The dark colour of the heart of oak, as contrasted with oak of very recent growth, is an illustration of this fact, as is also the deep colour which is met with in ebony and rosewood.

A third duty under this head is that of giving stability to the tree. It only requires a moment's reflection to enable the mind to appreciate the vast power of resistance which is placed in forest trees. The oaks of an English forest have stood a thousand years, notwithstanding the hurricanes and storms to which they have been yearly subjected; and a familiar illustration of the most violent storms, of which we hear and read, is that of the tearing up by the roots of the large forest trees. How mighty must be that power which can withstand influences so terrific as those which each person must have occasionally witnessed! This power is partly due to the mere mechanical hold which the roots have of the soil; but the tenacity of that hold is almost entirely due to the woody tissue contained in the roots and stem. Again, it is no uncommon occurrence in our old English parks to find branches of old trees which stretch from the trunk to the distance of fifty feet, and which in circumference are as large as trees of considerable growth. These do not stand perpendicularly from the ground, but pass out of the stem at an angle which is in some instances nearly a right angle, and must therefore be kept from falling directly in opposition to the effects of gravity. The strain exerted by such a branch is enormous; and yet the branch is maintained in its position for hundreds of years by the simple cohesive strength and tenacity of a series of woody fibres, each one-sixth smaller than a human hair, and too minute to be appreciated by the naked eye. It is probable that no mechanical agency at present in operation could effect that which is thus so readily effected by nature with the most simple agencies.

2ndly. Such as benefit man.

We do not refer to the almost infinite uses to which wood, in boards or masses, is applied by man, and the vast multitudes of beautiful objects which his ingenuity has enabled him to prepare out of the varieties of wood which nature has so bountifully provided.

Not less useful is the same woody fibre when reduced to very minute bundles or threads.

When the fibres are obtained in tolerably large bundles, they are used in place of bristles for street brooms, and especially when obtained from the cocoa-nut palm.

The flax and hemp which are imported so largely into this country, consist of woody fibre, obtained not from the wood of large trees, but from the stems of slender plants. From this raw material, ropes, sacks, linen, lawn, and other textile fabrics, are now made, as some of them have ever been by all nations. Uncivilized, or partially civilized nations, have been accustomed to use the bark of various trees offering this woody fibre in a very divided condition; and from this have prepared ropes and other articles of utility. It has long been known that cordage of a very strong kind was used by the ancient Egyptians, anterior, in all probability, to the building of the Pyramids; and Mr. Layard has recently exhumed sculptures which show that the yet more ancient Assyrians removed their gigantic winged bulls and other objects by cables of great size and strength.

The bark of the lace-tree (*Lagetta lintearia*) yields a net-work of woody fibre of exquisite beauty, and of great utility, and is used by the natives of that clime as a ready prepared fabric.

An indisputable proof of the antiquity attaching to the use of this fibre is afforded

in the fact, that the mummy cloths of the ancient Egyptians, which are nearly five thousand years old, are found to be composed of this material.

At the present day, this tissue is abundantly used, and is derived from very various sources. Its relative value depends upon the fineness and evenness of the fibre, and upon its elasticity. It has been found that certain kinds of flax have very great powers of resistance when exerted in a straight line, but readily break when they are bent. This is the case with the New Zealand flax; and its brittleness is to be attributed only to the nature of the material deposited within the tube. The flax obtained in this country, in Ireland, and India, from the *Cannabis*, has less resisting characters; but as it does not break so much in the process of hackling, has a higher marketable value. The pine-apple fibre is very capable of minute subdivision, and is very resisting, and consequently very fitted for the manufacture of fine fabrics. Cocco-nut-palm fibre is also very strong from the presence of secondary deposits.

The cost of flax has induced mercantile men to use woody fibre of less durability, but at the same time of a less costly kind—such as that derived from the China-grass, a species of nettle (*Urtica*); and from it much of the less durable linen cloth and pocket-handkerchiefs are now produced. It is well known that the tissue now under consideration occupies a medium between silk and cotton, as it regards resistance durability, and cost.

Silk is the produce of a member of the animal kingdom (Fig. 62 D), and occupies the highest position in the qualities referred to. Labillardière ascertained that bundles of fibres of equal size, of silk, flax, and cotton, gave the following unequal powers of resistance, on the application of a weight:—

Silk supported, without breaking, a weight of . . . 34lbs.

New Zealand flax (*Phormium tenax*) . . . 23½

Hemp (*Cannabis*) . . . 16½

Flax (*Linum*) . . . 11½

Pita-flax (*Agave Americana*), 7

The resisting powers of cotton are much below the lowest now indicated.

In order the better to appreciate the characters of these textile materials, single fibres of each have been selected and placed side by side (Fig. 62), and to these have been added hairs, or fibres of wool, and silk. These have not only been used largely for centuries in the manufacture of woollen cloths, but the former is found woven with cotton in mummy cloths obtained from Otaheite.



FIG. 61.—AGAVE AMERICANA OR FLAX PLANT.

The last use to which we shall now refer, is that of affording saccharine juices to man. This is known familiarly in this country in the wine obtained from the fermented juice of the birch tree (*Betula alba*). It is still better known in the Northern and Western States of America, and in Canada, from the sugar-yielding maple (*Acer saccharinum*). This is

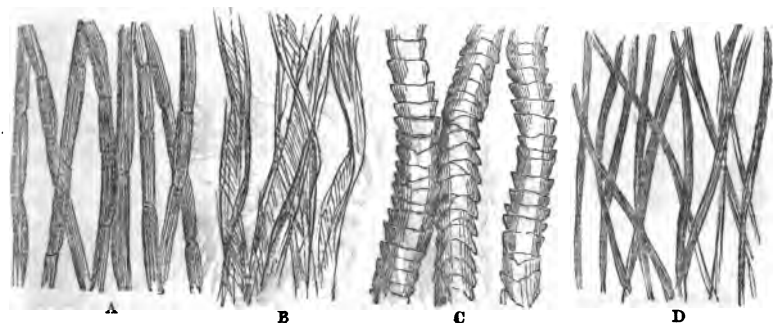


Fig. 62.—Fibre of flax, A; of cotton, B; of wool, C; and of silk, D; placed side by side, so that their relative size and markings may be readily contrasted. The fibre or cells of cotton are manifestly much thinner, and less resisting, than those of the other substances.

still a greatly valued product in the less accessible parts of the country; but the introduction of the cane sugar of the Southern States is gradually supplanting it in public estimation. The sugar obtained from it is very brown, but sweetens well, and will probably be one of the treasures of the happy homewife in the fertile paradise of the "far west" for many years to come. In both of the above instances the juice is collected in a similar way—*viz.*, by boring one or more holes into the stem of the tree at the period of the year when the sap has most accumulated; and, as the sap exudes, collecting it in vessels placed at the foot of the tree. The sugar is thence obtained by mere evaporation and subsidence; but the wine requires the subsequent process of saccharine fermentation.

The spruce-beer in use in Norway, and the refreshing juices of India, are obtained in a similar way, and from the same vessels—*viz.*, woody and pitted tissues.

Palm-wine is a delicious beverage, obtained from various species of palm, but especially from the cocoa-nut palm (*Cocos nucifera*), the gomuto palm (*Saguernus saccharifer*), and the magnificent Palmyra palm (*Borassus flabelliformis*). The latter is the most widely distributed of all the palm tribe, since it inhabits all the various regions of the Continent and Islands of India. Mr. Fergusson, in the first illustrated book which proceeded from Ceylon, has given a most valuable account of the palm trees of Ceylon. We counsel our readers to peruse it attentively, and especially that portion which describes the Palmyra palm and its products. The juice is procured by crushing the young inflorescence, and cutting off the upper part. It is then collected in a vessel attached to the cut end, and the daily discharge of the sap is facilitated by cutting a new slice every day. The fresh sap, called *taree*, or toddy, is very refreshing; and, if allowed to evaporate, yields a deposit of coarse sugar, or jaggery. When fer-

mented, it becomes a very excellent wine, and the most intoxicating of all tropical beverages.

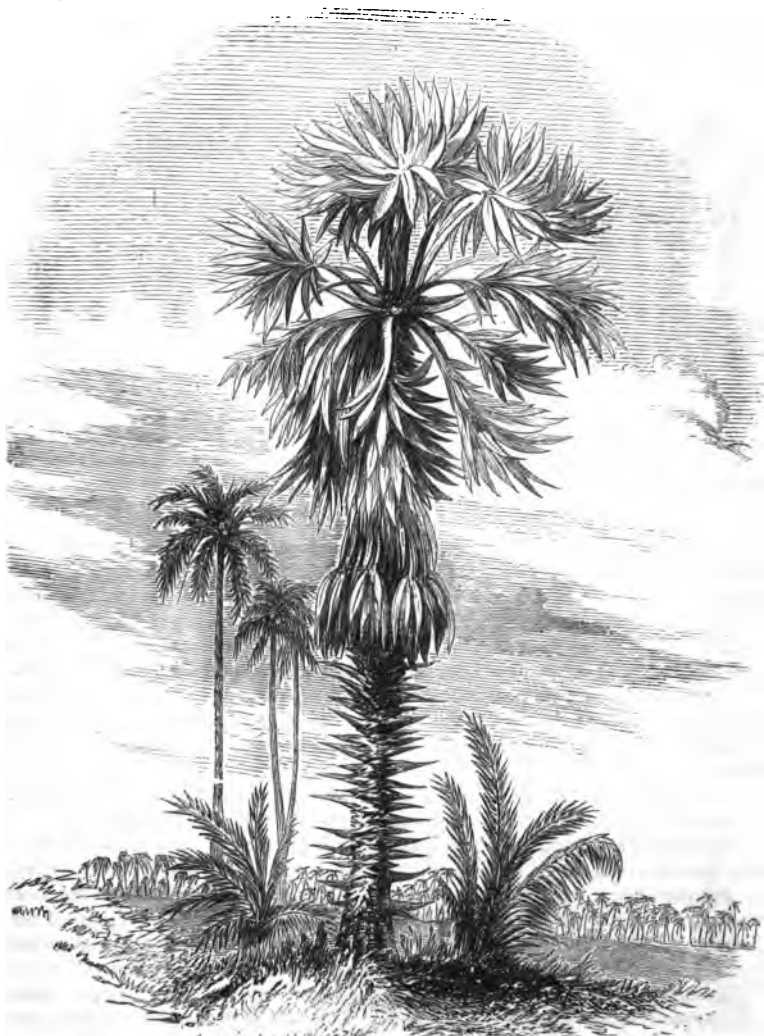


Fig. 63.—The PALMYRA PALM (*Borassus flabelliformis*) yielding Palm Wine.

The size of woody fibre varies from $\frac{1}{150}$ to $\frac{1}{3000}$ part of an inch, and is the largest in hot climates, for the reasons already indicated.

The position of woody fibre is readily determined. stems of wooded trees, but is found in single bundles in the stems of delicate herbaceous plants, and may be readily seen there when the stem is torn across. In a similar manner it occupies the thin cuticle of herbs, and may be readily observed in the ridges, or veins, which run from the root upwards. It is also met with in the bark of all trees, in the veins of leaves and flowers, and even accompanying the spiral vessels into the fruit of plants.

Vascular Tissue or Trachenchym.—The tissues which we have already described are chiefly devoted to the circulation of fluids, or to the inclosure of solid substances. Those, under this head, are in great part associated with the transmission of air within the plant. They are divided into two classes—*viz.*, spiral vessels and ducts, and are, perhaps, the most beautiful microscopic objects in plants. It is not at all times easy to distinguish between these two classes of structures, since both consists of thin membrane in a tubular form, and inclosing a fibre wound in a spiral direction. The theoretical distinction is, that the fibre of the spiral vessel may be unrolled without breaking, whilst that of the duct is inseparably connected with the membrane, and cannot be unrolled in its integrity. This general distinction is doubtless correct; but an unrolled spiral vessel, and a duct, in which the membrane connecting the spiral fibre has been destroyed, have a very close resemblance to each other. It is highly probable that the distinction is less one of nature than one established by botanists as a matter of convenience.

The SPIRAL VESSEL is a cylindrical tube with conical extremities, and having one or more fibres wound as a right or left-handed screw, which may unroll without breaking. It has been disputed whether the fibre is placed within or without the membrane, and whether it is solid or hollow; but we are of opinion that it is inclosed by the membrane, and that it is always solid. These vessels are not individually

of great length, but are connected together by their conical extremities; and it is not unusual to find the intervening partition ruptured. When but one fibre is inclosed the vessel is termed a simple spiral vessel (Fig. 64 A); but when two or more exist, it receives the appellation of compound (Fig. 64 B & C). In some instances, upwards of twenty fibres have been counted in a compound spiral vessel. The spiral vessels are very numerous in

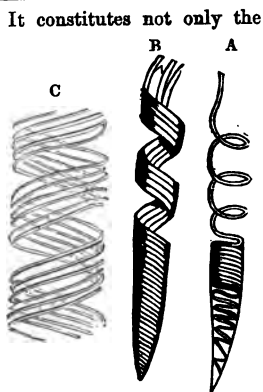


Fig. 64.—Spiral Vessels.

A, a simple spiral vessel, that is, having but one fibre. The lines bounding the pointed extremity represent the inclosing membrane.

B, a compound spiral, or a vessel composed of many fibres, wound in a spiral manner.

C, a compound spiral from the *Canna bicolor*, with five spiral fibres: more highly magnified.

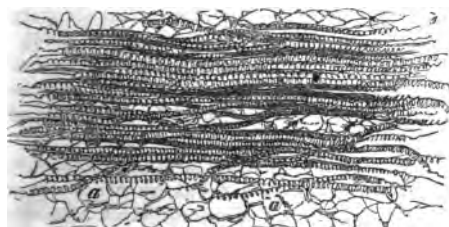


Fig. 65.—A bundle of spiral vessels from the veins of the hazel nut (*Corylus avellana*), showing their great number and very minute size. They are embedded in a mass of hexagonal cellular tissue, as represented at a. Magnified 200 diameters.

all flowering plants, but more so in certain bulbous plants, as that of a squill growing in the neighbourhood of the Mediterranean. The inhabitants collect them, and tie them in bundles to be used in the lighting of cigars—an office for which their smouldering flame renders them well adapted. They are met with in all parts of plants except the roots, but more particularly immediately surrounding the pith, and in all parts emanating from it—viz., branches, leaves, flowers, and fruit. They may be readily obtained by cautiously cutting through the cuticle of the footstalk of the strawberry-leaf (*Fragaria*), and then gently separating the divided portions, when they appear as very fine threads arranged in loose spires. They abound in the veins of leaves, and even in the minutest parts of the most delicate flowers. They are also found in the foot-stalks of all fruits, and in the vascular bundles which enter the minutest seeds. This may readily be seen by tearing the seed of the strawberry from the fruit, and placing it in water under the microscope. The spiral vessel is there exceedingly minute and beautiful.

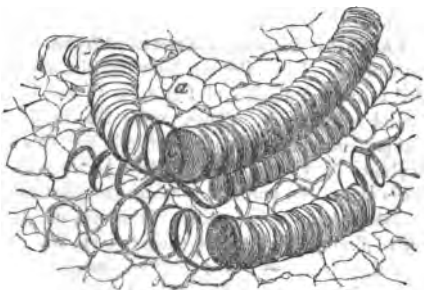


Fig. 66.—A portion of a bundle of spiral vessels from the stem of the potato plant (*Solanum tuberosum*), embedded in loose cellular tissue, as represented at *a*. The tubular character of the tissue is well seen at *b*, where the separation of the fibres permits the observer to look within the tube. At that point also the inclosing membrane is well delineated. These are of large size, and, with those of Fig. 65, may well represent the two extremes of development. Magnified 200 diameters.

Perhaps, of all positions in which it may be the best inspected, that of the veins running over the brown coating of the common hazel nut (*Corylus avellana*, Fig. 65), after the shell has been removed, is the most accessible. The brown membrane should be soaked in water for a short time, and then the veins carefully torn open with needles, and placed under the microscope. If the light be not passed through them, but be allowed to fall upon them, they appear as bundles of beautifully-white glistening lines, consisting of scores of very minute spires.

Such is also the case with other similar fruits, as those of the walnut (*Juglans regia*) and chestnut (*Fagus castanea*). They are seen to great advantage also in certain succulent stems, as those of the potato, by cutting the stem across obliquely with a knife in bad condition, and the section placed under the microscope (Fig. 66).

They are of very delicate structure, and require other tissues to inclose and protect them. This is chiefly performed by the woody fibre, and thus each vein of a leaf or herbaceous stem has its central bundle of spiral vessels inclosed in a covering of woody fibre.

The use of the spiral vessel has been the subject of much investigation, and it appears probable that at some period it conveys air charged with an increased percentage of oxygen, and thus becomes a system of internal respiration, much after the manner of the distribution of the tracheæ in insects. At a later period of its existence it is probable that it contains fluid. The spiral fibre is valuable at either of these periods as keeping the tube open, but more particularly when the cavity is filled by air only.

Ducts are tubes with conical or rounded extremities, and their sides marked by transverse lines or bars. Their size is about twice that of spiral vessels. Their appearance is very various, and depends upon the direction of the spiral fibre which assimilates ducts to spiral vessels, or the presence of other internal deposits, which renders them not unlike pitted tissue.



Fig. 67.—Ducts.

When the spire is so arranged as to differ from that of the spiral vessel only in that it cannot unroll, the vessel is termed a *closed duct*. When it is broken up at intervals, so that single coils shall be detached, the term *annular* is applied (Fig. 67), and properly represents the rings which are so commonly found in ducts. This form is said to be due to the rapidity of the growth, whereby the fibre is carried along more rapidly than the membrane can be produced.

The *reticulated* duct is perhaps the most interesting of the various kinds of ducts, and appears to be formed either by two fibres wound in opposite directions so as to cross each other, or by a single fibre which breaks and anastomoses at intervals. The characteristic feature is that of a net-work. All these various forms of duct, and also other modifications, may be found in the stem of a full grown garden balsam. The succulent stems of herbaceous plants are the more common positions in which ducts are found; but they are abundantly met with in the softer kinds of wood, as of the lime-tree (*Tilia*), willow (*Salix*), or birch (*Betula*).

We cannot omit to refer again to the analogies which exist in the structure of animals and vegetables. Thus, in the animal kingdom, we have a tube which very closely resembles a spiral vessel,—*viz.*, the tracheæ of insects. This is clearly shown in the accompanying figure of the *Dytiscus* (Fig. 68), which represents a tube made simply of a fibre inclosed by membrane.



Fig. 68.—The tracheæ or air-tube of the larva of the water-beetle, having many of the characters of a vegetable spiral duct.

It is unnecessary to refer to all those forms of duct in which we find a secondary deposit so arranged as to give the appearance of pits, since we have already considered similar structures under the head of *Bothrenchym* (pp. 7 and 17). But there is one not described as yet—*viz.*, the *Scalariform* or *ladder* duct. This is so called from the resemblance which the transverse lines bear to the rounds of a ladder. The *scalariform* duct is of considerable size, and usually six-sided, and has a deposit so arranged, on its inner side, that either its presence or its absence causes certain transparent lines to appear at very regular intervals. In some instances so many as twelve sides have been observed; but whatever may be the number of sides, they are separated by clearly defined perpendicular lines. The transverse bars do not



Fig. 69.—Scalariform vessel, showing the transverse bars on nine sides, and the open character of the tube.

pass quite so far as the boundary line of the side—a circumstance which gives a greater degree of resemblance to the figure of a ladder. As there are transverse translucent spaces of about equal size and at equal distances, there will, of course, be alternate transverse and equal bars separating these spaces. These bars

are continued with the boundary line of the side; and, upon the whole, it appears probable that the deposit has been placed at these points, and that the translucent

lines or pores are the parts at which no deposit has occurred. If this deposit has taken place in the spiral direction so commonly found in vegetable deposits; but it is quite certain that in a few instances the scalariform has unrolled like a spiral vessel (Fig. 70). The use of these vessels differs little, if at all, from that of other ducts,—*viz.*, that of conveying fluids with rapidity; but there is this great peculiarity, that they are found only in one class of plants—*viz.*, the ferns (*Filices*), and there supplant all other forms of vascular tissue (Fig. 71). Thus there are two great classes of plants which have distinguishing anatomical characters; *viz.*, the *Conifera* or fir tribe, distinguished by its glandular woody fibre, and the fern tribe, known readily by its scalariform tissue. The scalariform tissue is also enduring in a remarkable degree, as was stated of the glandular woody tissue; for ferns, like firs, are abundantly found in the coal measures, and Professor Quekett discovered it in a funereal urn dug up in the island of Anglesey.

It is still in dispute



Fig. 70.—A portion of a large scalariform duct, with nine sides unrolling like a spiral vessel, and showing a close analogy with spiral structures.

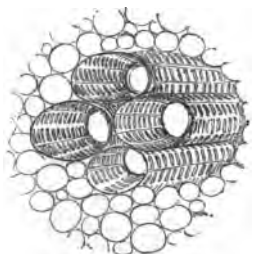


Fig. 71.—Bundle of scalariform vessels enclosed in cellular tissue in the common brake fern, the *Pteris aquilina*.

This appears a favourable point at which to request the reader to look back and observe the unity of design which appears to pervade the whole structure of plants. We have just seen that there is not, in truth, any essential distinction to be made between the three classes of vascular tissue now described—spiral vessels, ducts, and scalariform vessels, all of them being composed of a membranous tube, with a secondary deposit assuming the spiral direction. It is also evident that these differ in no essential respect from Bothrenchym or pitted tissue; and from dotted cells and fibre cells, only in size and figure. Thus we have traced the essential identity of the tube with the cell, and of the highly-figured vascular tissue with the simpler cells with a secondary deposit. The woody tissue is, in like manner, an elongated cell of thickened membrane.

The arrangement or classification of these structures is not as yet in a satisfactory condition, and it is yet a desideratum to find out some general feature by which they may be grouped in a less artificial manner. That one which has already been referred to—*viz.*, the simple membrane and the membrane with a secondary deposit—as the basis of all tissues, is a step in the right direction. It is clearly unphilosophical to regard mere markings as points of distinction, where there is not real difference in structure and functions. So far as we have now accompanied our readers there can be no difficulty in acknowledging that we have simply passed through modifications of a simple cell.

Laticiferous, or Milk-bearing Vessels.—There is yet another very interesting and somewhat less simple form of tissue to be described—*viz.*, the milk-bearing tissue so readily inferred to exist from the white exuding juice of the cut dandelion (*Leontodon*), and poppy (*Papaver*), or the yellow juices of the *Chelidonium*. The essential characteristics of this tissue is its branched distribution, and the intermitting or pulsatory motion of its contents. In both these respects it differs from other vegetable tissues, and corresponds very closely with the blood-vessels of animals. It is well

known that nature never progresses by bounds, but by gentle ascents, and that, not only does one fundamental structure run through the whole of vital existences (whilst the anatomical characters of widely-separated classes are yet very distinct); yet that there are certain similarities which become, as it were, the larger links which unite them together. The structure now under consideration is the large link which binds vegetables and animals together. No other vegetable vascular tissue uniformly branches, and none has a pulsatory motion of its contents; but both these conditions are universal in the animal kingdom. There is yet another similarity:—The *Lacticiferous* or milk-bearing tissue (Fig. 72), is devoted to the maintenance of the vitality of the other vegetable structures, and not to any extraneous object whatever. If a stem be in great part cut through, the effect is to kill the plant—not so much by destroying its functions as by pouring out the milky juice, which should maintain the life of all the structures—in fact, by bleeding it to death. This is not the



Fig. 72.—Milk vessels from the stipules of the *Ficus elastica*, or India-rubber fig-tree, showing the branched and ramifying character of the tubes, and the granular nature of their contents.



Fig. 73.

Fig. 73.—The smallest vessels or capillaries of the frog's foot, as seen by the microscope, whilst the circulation is proceeding. *a* indicates a vessel of a larger size, which subdivides at *b* into the capillaries. The vessels anastomose with each other, and branch in every direction, and contain the oval bodies, or blood globules, which correspond to the granules in Fig. 74.

Fig. 74.—Milk-vessels of a water-plant—the *Limncharis Humboldtii*, showing their granular contents; and the walls apparently made up of a series of oblong cells of cellular tissue, and the whole inclosed in hexagonal cells, as shown at *b*. The arrows indicate the direction of the current.



Fig. 74.

case with the woody tissue; for if that were nearly drained of its contents the plant would not necessarily perish; but if the milky juice be withdrawn too abundantly

—as from the cow-tree (*Palo de Vacca*) of Ceylon, or the hya-hya tree, of British Guiana, which yields refreshing juices—the plant droops and dies.

The similarity between this structure and the blood-vessels of animals is well seen in diagrams, Figs. 73 and 74, which represent, side by side, the capillaries or smaller blood-vessels in the frog's foot, with the contained blood highly magnified, and the *lactiferous* tissue, with its contents.

The undulatory or pulsatory motion of the contents of the tissue may be well seen in the *Limnœcharis Humboldtii*, a water-plant found in hot-houses (Fig. 74), if a portion be cut off, and exposed to the sun for a short time, and subsequently placed in water. The exposure to the sun causes so much evaporation as to greatly lessen the quantity of fluid in the vessels; and the subsequent immersion in water enables the plant

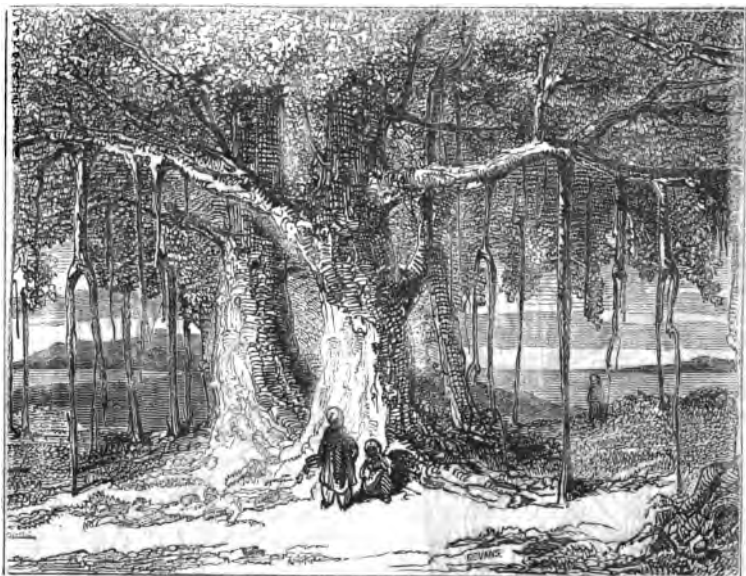


Fig. 75.—The BANYAN TREE (*Ficus religiosa*), showing its original trunks, and the branches which have passed down to the ground and taken root, and have become new centres of growth and nourishment. This tree is so large that a regiment of soldiers may take refuge in its shade.

to supply its wants, and to pump, so to speak, vigorously. This diagram is also illustrative of the opinion formed by certain authors as to the relations of this tissue—*viz.*, that it is very analogous to mere inter-cellular passages. In this view, it is not a distinct tissue, although it may have special functions.

The latex, or milky fluid, is of immense service to man, in two ways more particularly:—

First—As already intimated, it constitutes refreshing beverages, readily obtained, and in large quantities, to travellers in the sunny climes of Asia. Such are the cow-tree of South America, the kiriaughma (*Gymneuralactiferum*), and hya-hya (*Jabernamantana utilis*) before-mentioned, and also the *Euphorbia balsamifera*, of the Canary

Islands, the juice of which, as a sweet milk, or evaporated to a jelly, is taken as a great delicacy, and the Banyan tree (*Ficus religiosa*—Fig. 75). Many of these juices also contain medicinal properties of great value.

Secondly—In the production of caoutchouc, or India-rubber. This invaluable substance is found in all plants, but more particularly in the Fig, Euphorbia, and Cactus trees of the East Indies, South America, and Africa within the torrid zone. Of all these, the fig, known as the *Ficus*, or *Siphonia elastica*, is the most valuable; but in the countries where the manufacture of India-rubber is a daily occupation, it is not exclusively selected. This increased quantity of caoutchouc in the latex of hot climates is believed to be due to the powerfully elaborating property of the sun's rays in those climates.

The following is the mode in which the India-rubber is prepared from the milky juice:—

The natives having selected a fine specimen of the *Siphonia elastica*, sixty feet in height, make deep incisions into its smooth, brownish-gray bark; after which the white juice flows forth in considerable abundance. Before it dries upon the trunk, or in a hole at the foot of the tree, it is spread over bottles of unburnt clay, and dried over a smoking fire; care being taken to prevent the flame burning it. When it is dried, another coating of the juice is placed upon it, and that again is held over the fire; and the process is thus repeated, until the required thickness has been attained. When the process is completed the bottle of clay is broken and the pieces extracted; after which the Indian-rubber is ready for the market. It is met with in commerce of various colours, terminating in a deep black; but the juice is originally colourless, and the colour is produced by the smoke in which it is immersed in the process of drying.

This tissue is found in all parts of a plant; but, from its ramifications amongst other tissues, cannot be readily separated. It is most readily seen in the fresh stipules of the *Ficus elastica*.

Gutta-percha is another invaluable substance, recently obtained from the latex of certain plants, and especially of the class called *Sapotacea*, abounding in the Indian Archipelago. The trees whence it is obtained are large, but not otherwise valuable. The gutta-percha is obtained by incising the bark and collecting the milky juice, which speedily coagulates. Each tree yields from twenty to fifty lbs., so that the destruction of a large number of trees is required in order to meet the present enormous demand for this article of commerce. It appears that the proper term is Gutta-Pulo-Percha—gutta signifying gum in the Malay language, and Pulo-Percha the island whence it is obtained. When translated into English words, it is—"gum of the ragged island."

The Secretions of Plants.—We now proceed to describe the chief secretions of plants, some of which are of the utmost value to man. They are—Starch, Raphides, Silica, Oils, and Fats, and the colouring principles of plants.

Starch.—This alimentary substance was, until recently, believed to be peculiar to vegetables; and, although it is not strictly, it is almost exclusively confined to them. It is, moreover, the chief element in vegetables, which renders them fit to be the food of animals, and enjoys, therefore, a position of the utmost importance. Starch is not to be understood as directly represented by the article of commerce which bears its name; for, although that is starch, it has been so prepared as to lose the anatomical characteristics which starch in its natural state possesses. All plants, probably, possess this substance, but in very unequal degrees; and it is only when it exists in quantities much greater than the plant requires for its own purposes that it is sought after by

man. As a rule, a vegetable, if nutritious at all, is so in proportion to the amount of starch which it contains; but there are many plants which yield starch in tolerable abundance, but which are inedible from the presence of acid or poisonous fluids. In selecting articles of food, it is needful to bear both these facts in mind. It is most abundantly found in the seeds of plants, and especially in the cereals, or wheat tribe; and thence this article of diet is accounted to be very nutritious. It is also met with in the cellular tissue of plants, and especially in the cellular matrix of such underground stems as the potato, turnip, and radish, and the stems of such plants as the sago-palm-fig, whence it is obtained in large quantities. Green vegetables contain a considerable proportion of starch at the period of their maturity; but they are nutritive beyond the quantity of starch contained by them, since the vegetable structure itself has a very similar chemical composition to that of starch. Starch is also found in the bark of trees; and, during periods of famine, the bark of certain trees in this country has been made into bread.

This practice was more common in the northern countries, where Nature has less bountifully distributed her treasures. Mr. Laing, in his interesting "Journal of a Residence in Norway," states that he observed many trees which had been thus dilapidated; and, after referring to the country mode of grinding meal, remarks—"This mode of grinding and baking makes intelligible the use of bread of the bark of the fir-tree in years of scarcity. Its inner rind (*liber*), kiln-dried, may undoubtedly be ground along with the husks and grain, and add to the quantity of meal—it may even be nutritious. I had previously been rather disposed to doubt the fact, and to laugh at the idea of a traveller dining on sawdust pudding and timber bread. In years of scarcity, however, this use of fir-bark is more extensive than is generally supposed. The present dilapidated state of the forests is ascribed to the great destruction of young trees, for this purpose, in the year 1812."

But, notwithstanding its universal distribution, it is to be found in quantities only in the storehouses provided by nature—*viz.*, the seeds and fruit of plants; the potato (*Solanum tuberosum*), carrot (*Daucus carota*), turnip (*Brassica rapa*), and similar underground stems, as they are termed; and, lastly, the stems of palms, and similar *endogenous* plants.

Amongst plants which yield an acrid juice with the starch, we may first mention the tapioca plant, or *Yucca dulce*, the sap of which is used to poison the arrows; but the starch is fitted for food after the roots have been beaten, dried, heated, washed, and pressed. The common *arum* of this country was formerly collected on account of the starch or arrowroot contained in its corm or underground stem; but the aridity of the juice was so great as to cause the hands of the operator to inflame.

The horse-chestnut is not edible for the like reason, although it contains much starch, and is excellent food for some inferior animals. It is also known that whilst the tubers of the potato are so wholesome, the berries are poisonous. The horse-chestnut was tried in this country as an article of diet in 1846, but its acidity arrested its use.

Those plants which offer the starch unmixed with deleterious matters are:—

1st. All the grasses, including, wheat, oats, barley, rye, and all trinclar seed-bearing plants.

2. Many leguminous and *cruciferae*, or pod-bearing plants, such as the pea, bean, and lentil, cabbage, and turnips.

3. The *Maranta arundinacea*, or arrow-root plant.

4. The sago palm.

5. Several bulbs and tubers, as the onion and potato.

6. A species of plantain, which offers it so abundantly and in small masses that it was introduced and sold in this country as flour.

The most interesting illustration of the admixture of deleterious and edible substances is that of the preparation of the Cassava meal, a kind of arrow-root, from the *Mandioca farinha*, a tree possessing excellent starch, and, at the same time, the most poisonous juices. Its preparation is thus graphically described by M. Schleiden :—

“In a dense forest of Guiana the Indian chief has stretched his sleeping mat, between two high stems of the magnolia; he rests indolently smoking beneath the shade of the broad-leaved banana, gazing at the doings of his family around. His wife pounds the gathered mandive roots, with a wooden club, in the hollowed trunk of a tree, and wraps the thick pulp in a compact net, made from the tough leaves of the great lily plants. The long bundle is hung upon a stick which rests on two forks, and a heavy stone is fastened to the bottom, the weight of which causes the juice to be pressed out. This runs into a shell of the calabash gourd (*Crescentia Cujete*) placed beneath. Close by squats a little boy, and dips his father's arrows in the deadly milk, while the wife lights a fire to dry the pressed roots, and by heat to drive off more completely the volatile poisonous matter. Next, it is powdered between two stones, and the cassava meal is ready. Meanwhile, the boy has completed his evil task; the sap, after standing some considerable time, has deposited a delicate, white starch, from which the poisonous fluid is poured off. The meal is then well washed with water, and is their fine white tapioca, resembling in every respect arrow-root.”—Let not our readers be alarmed when they eat their next tapioca pudding; but yet it may be well to remember how closely life and death are associated.

Starch is met with in two forms :—

First, amorphous; that is in fine powder, without any distinct form or marking, as in the *Salep*, commonly sold in this country.

Secondly, and almost universally in the form of variously-figured cells.

We have nothing to add in reference to the former, except that, in common with the other form, it is found inclosed in the large cells of vegetables, as may be seen in the section of the potato (Fig. 83), and that the presence of both alike may be chemi-



Fig. 76.—The *ARUM MACULATUM*, with its cormus, or root, containing starch.

cally demonstrated, if a drop of a solution of iodine be added to the smallest quantity of starch and water, and placed under the microscope. The chemical effect of the iodine is to colour the starch of a beautiful deep violet shade. We may also add, that as starch has the property of polarizing light, its presence may be readily shown by placing it in the microscope with the polarizing apparatus.



Fig. 77.—The SAGO PALM (*Cycas revoluta*), containing a large quantity of starch in its stem.

Further attention is, however, necessary to the consideration of the second kind of starch, or that consisting of cells; and chiefly on the ground, that it is possible to distinguish the starch grains or cells of one plant from those of another, and thus to detect the adulterations which are practised in reference to flour, bread, arrow-root, and other articles of farinaceous food. Much attention has been given to this matter during the past ten years, and with the result, it is believed, of having lessened, at least, the frequency with which fraud has been perpetrated.

Starch grains are distinguished from each other by their size, figure, and markings.

In reference to their size it will suffice to glance at Fig. 78, to show that it varies very greatly, and that it is very small in the rice (Fig. 78 *a*), and very large in the *Toules Moïs* (Fig. 78 *b*); whilst wheat (Fig. 78 *c*) and potato (Fig. 78 *d*) starch occupies a medium position. The ordinary figure is rounded or oval, sometimes much flattened, as in the *Curcuma leucorrhiza*, or East Indian arrow-root; less flattened, as in the wheat and barley; oval and roundish, as in the potato and the pea (Fig. 78 *i*). The figure however, although permanent in each variety in its general characteristics, varies considerably. In every specimen a multitude of smaller or imperfectly-developed granules will be observed; and they do not assume the form which is obtained by the perfect granule. The consideration of the markings and their nature is the most interesting and important part of the subject, inasmuch as they are most permanent, and imply an acquaintance with the structure of the cell. We shall therefore say a few words in reference to the composition of the starch grain before we describe the markings which distinguish the various kinds of starch.

A reference to Fig. 78 will show that in almost all instances there is a central spot (Fig. 78, 1), called the hole or hilum, and that a series of lines arrange themselves around it. This will be better seen in Fig. 78 *e*, which represents the cell much more highly magnified. The nature of both of these is the point in dispute. There is a cell-wall, as may be seen in Fig. 78 *g*, in which, on the application of heat, it has ruptured, and is a little reflected. But is there no central cavity, and do the lines observed on the granules correspond with layers within the cell-wall? There have been two leading views on these points.

1st. That the starch granule is really a vesicle or cell, having an inclosing wall, differing in consistence; and perhaps in chemical characters, from the starch itself.

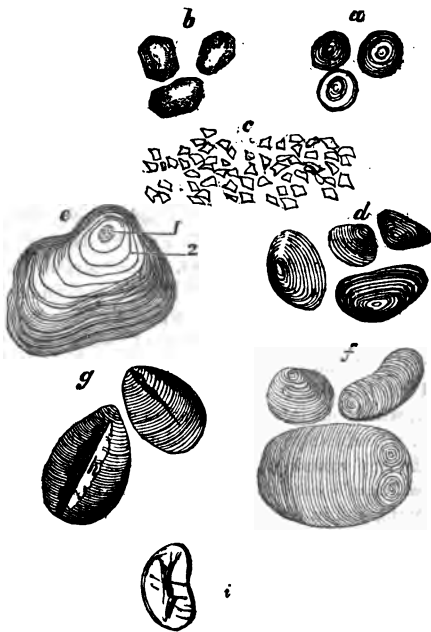


Fig. 78.—The more common forms of the starch cell.
a, rice, very small and angular.
b, sago, larger, rounded, and granular.
c, wheat, do., do., faintly marked with concentric lines.
d, potato; medium size, flattened, and with well-marked lines.
e, the same, more highly magnified, so as to show the nucleus, 1, and the markings, 2.
f, *Toules Moïs*, the largest kind of starch, of oval shape, well-developed markings, and sometimes with a double hilum, 1.
g, the same, ruptured by the application of heat, so that the membrane at *h* is retracted and corrugated, and the contents exposed.
i, the starch of the common pea (*Pisum*), with its deep central folding or cavity. The precise figure of this cavity or folding differs in various grains.

2nd. That it is a solid body, constituted by layers one upon the other, beginning either within (centripetal), or without (centrifugal).

On the first of these theories the markings upon the surface are produced by the folding of the cell-wall; and on the second, by the successive layers of the solid starch.

Leeuwenhoeck, a celebrated microscopist, published certain investigations made by him nearly a century and a-half ago, in which he showed the cellular character of starch. Since his era many eminent observers have adopted his views, with certain modifications; and very recently two, whose experiments we shall describe, —viz., M. Martin, the librarian of the Imperial Polytechnic Institute at Vienna, and Mr. Busk, a distinguished naval surgeon and microscopist. Both these gentlemen agree in the theory of the constitution of the starch granule—viz., that it is a cell, having a cell-wall much larger than the contents of the cell in the dried state, and, therefore, puckered and plaited, as indicated by the lines upon the surface. M. Martin says, that “the primary form of the starch grain is a spherical or ovate cell. If this be considered as empty, and so contracted that one-half lies in the other half, a watch-glass-shaped basin is formed, which, after boiling and pressure between two glasses, appears, in consequence of the delicacy and elasticity of the membrane, as a flat, round-edged disc.” Thus, in his opinion, the ovate cell is inrolled upon itself.

Mr. Busk has not satisfied himself in reference to this unfolding of the membrane, but thinks that the swelling up of the cell by the addition of strong sulphuric acid rather indicates the distinction of plaits or folds, and more particularly in such varieties of starch as have, when dried, a puckered centre, as is exhibited in Figs. 78 i, and 80. As this is a most interesting and undetermined question, and one, moreover, which our intelligent readers who have microscopes may be desirous to investigate, we subjoin the methods adopted by the observers just mentioned.

In any examination of starch it is only necessary to take a pin's point of flour of wheat, or of some other grain, or to scrape a very little morsel from the cut surface of a potato, and in both cases the starch will be found partly in free grains and partly inclosed as masses of grain within the cellular tissue of the plant.

The grains of *Tous les Mois* (Fig. 78 f) are the largest, and therefore, in many respects, the most convenient for examination; as also those of the horse-chestnut (Fig. 79), and pea (Fig. 78 i), when it is desired to notice the unfolding of the central puckerings.

M. Martin's method was as follows:—“Between two very thin glasses, of the same size as the stage of the microscope, a little starch, with a sufficient quantity of water, is to be put, and the former well spread out with the finger, to prevent, as much as possible, the formation of bubbles. The number of starch grains in the field of view should not exceed ten or fifteen. The glasses should lie freely on the spring-piece, which must be raised by means of two pieces of cork, introduced below it, so that while the two glasses are lying right upon the object-bearer, a current of cold air will ascend from below, and permit the little flame to continue burning in the hole of or below the stage. As the glasses are wide they protect the microscope from too great a heat or other danger. The small flame is to be obtained from a common thread, doubled and slightly waxed. This, when ignited, gives a flame quite sufficient to boil the starch.”—The object of this experiment is to cause the distension of the cell-wall by the introduction within the cell of hot water, and thereby to notice what changes take place in the markings upon the surface.

Mr. Busk seeks the same end by applying the most powerful of acids—viz., concen-

trated sulphuric acid, or oil of vitriol. Our readers, whilst repeating this experiment, must exercise the greatest caution lest they burn their fingers and clothes. The following is Mr. Busk's method :—"A small quantity of the starch is placed upon a slip of glass, and covered with five or six drops of water, in which it is well stirred about ; and with the point of a slender rod of glass the smallest quantity of solution of iodine is applied, which is to be quickly and well mixed with the starch and water. Any excess of water must be allowed to drain off, leaving the moistened starch between, and a portion of it is then to be covered with a piece of thin glass. It must then be placed on the microscope, and a quarter or one-fifth object glass brought to a focus close to the upper edge of the piece of thin glass. With a slender glass rod a small drop of sulphuric acid is to be carefully placed immediately upon, or rather above, the edge of the cover, care being taken that it does not run over it. The acid, of course, quickly insinuates itself between the glasses, and its course may be traced by the rapid change in the appearance of the starch grains with which it comes in contact. The course of the acid is to be followed by moving the object upwards ; and when, from its diffusion, the reagent begins to act more slowly, the peculiar changes in the starch granules, now also less rapid, may be readily witnessed."

M. Martin thus describes the changes observed by him :—"First the starch grain

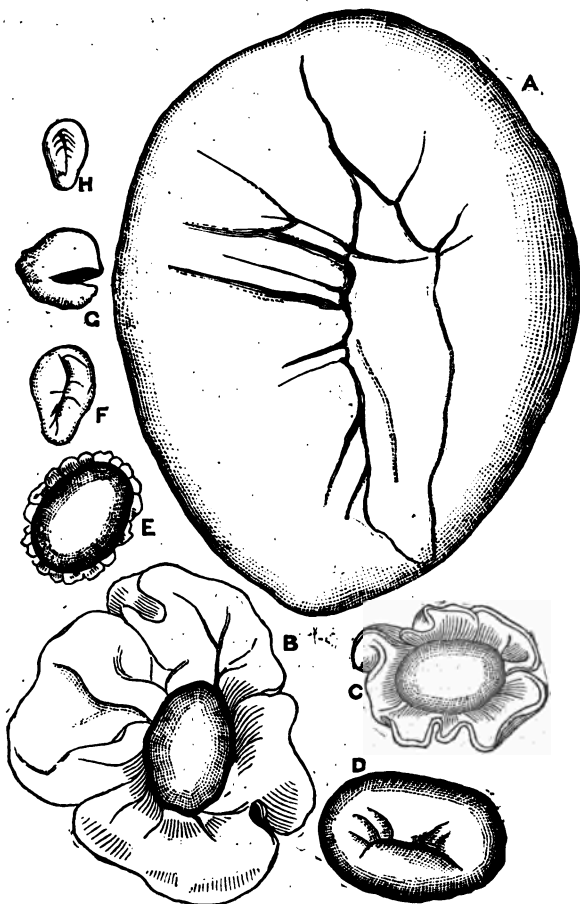


Fig. 79.

sinks in that place where the nucleus is situated. On the surface minute fissures appear, two of which almost regularly diverge towards the thicker end of the grain. The grain continues to be depressed inwards until a cavity is formed, which is surrounded by an elevated edge. In proportion as the grain swells up, this ridge increases in circumference, and decreases in breadth; that is, continues to get flatter, until fissures, mostly of a star-like form, appear in the hitherto little altered thicker part of the grain. The process is not very rapidly developed, and it is very difficult for the eye to follow it. Suddenly something is torn off, the grain is extended lengthways, and in the next moment a wrinkled skin of a rounded, generally oval shape, lies on the glass."—Further examination shows that they are collapsed bodies, consisting of an extremely fine, but strong and elastic, membrane.

Mr. Busk obtained a different impression from his experiment. He considered that the line upon the surface were simply plaits or foldings, and that the whole process consisted of unfolding these plaits, and, by distending the cell, to render the cell-wall perfectly plain and free from any markings. In Fig. 79 A, we have the starch of the horse-chestnut in its unaltered state, and at B is represented a stage of the unfolding which results from the use of the sulphuric acid. Fig. 79 C, D, and E, represent other views of this process, showing that the cell becomes gradually larger, until it reaches the great size figured at F. The fringe around the figures C, D, and E he regards as plaits in the process of being unfolded.

Figs. 80 a b, have been copied from Schlieden's work, and represent the starch from the *cormus* or roots of the *Arum maculatum* of our hedges, and of the *Colchicum autumnale*, in which the star-like centre is presumed by Mr. Busk to indicate the central folding of the membrane referred to by him.

On a review of the whole evidence now offered, we may infer that the starch granule consists of a cell-wall, contracted and plaited when dry, and smooth and distended when heated with moisture, and also of contents in insufficient quantity to fill it, and thereby leaving a central cavity.

On this principle, it is difficult to conceive that the plaits can retain the same characters in the same plants under all atmospheric conditions; and it is proper that we should state that Dr. Allman of Dublin has, during the present year, published an article in the Quarterly Journal of Microscopic Science, in which, by the same processes as those above indicated, he has come to totally opposite conclusions. In his opinion the statement of Fritzsche is correct—viz., that the starch cell is in fact a series of cells, placed within each other, as exhibited in Fig. 80 a. He sums up his opinions in the following words:—

1st. That the starch granule consists of a series of lamellæ, in the form of closed hollow cells, included one within the other, the most internal inclosing a minute cavity

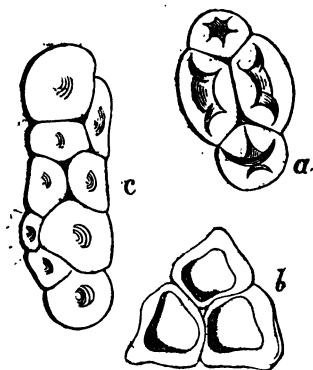


Fig. 80.—Starch cells copied from Schlieden.

a, those of the *Colchicum autumnale*.
b, those of the *Arum maculatum*, both showing in different degrees the central folding or cavity.
c, the central cavity well developed in the starch of the Iais.

filled with amorphous (?) starch; that the concentric striæ visible in the granula indicate the surfaces of contact of these lamellæ; and that the so-called nucleus of Fritzsche corresponds to the central cavity.

2d. That while the lamellæ appear to be all identical in chemical constitution, yet the internal differ from the external in consistency or other conditions of integration.

3d. That the order of deposition of the lamellæ is centripetal.

4th. That while the starch granule is thus a lamellated vesicle, it cannot be included in the category of the true vegetable cell, from which it differs, not only in the absence of a proper nucleus, but in presenting no chemical differentiation between membrane and contents.

So widely do equally eminent observers disagree in their description of the same object as seen by the same means!

Rice (Fig. 78 *a*) is known by the small size of its grains, by their angularity, and the absence of evident markings.

Sago starch (Fig. 78 *b*) is very much larger than that of rice, but still less than that of wheat; it is rounded, and its surface is rather granular than plaited.

Wheat starch (Fig. 78 *c*) occupies a medium position in point of size, and is more regularly round than any grain of similar size. Its markings are not so distinct as those of the potato.

Potato starch (Fig. 78 *d*) is distinguished from wheat starch by its large size, irregularity of outline, and flattened lenticular figure. The plaitings on its surface are very distinct, as is also the *hilum* around which they are gathered.

Pea starch (Fig. 78 *e*) is in size about equal to that of wheat; but it differs remarkably in its flattened figure and the star-like plaits which invariably occupy its centre.

Tous les mois (Fig. 78 *g*) is the largest of all known forms of starch, and from its size, void figure, and concentric rings, is not unlike a cocoon. It has occasionally two hilums or holes, and its markings are usually very regular. This article enters largely into the commerce of the day.

The starch grains, found in the *Euphorbias* (Fig. 82 *a*) are very characteristic, and are readily distinguished by their dumb-bell form from those of any other plant. The same grains are seen in Fig. 82 *b*, floating in the milky juice of the laticiferous tissue.

Wheaten flour, when adulterated with inferior starch, is usually mixed with potato, pea, or rice starch, each of which may be distinguished under the microscope. So also with wheaten bread, if the smallest crumb be broken up in water, and examined in the ordinary way.

It is not known if the varieties of starch possess any variation in the degree of their nutritive properties. It is therefore the quantity of pure starch which any substance can yield, conjoined with the abundance and ease with which the substance may be obtained, that gives the marketable value. It is also of importance to determine the state of perfection of any

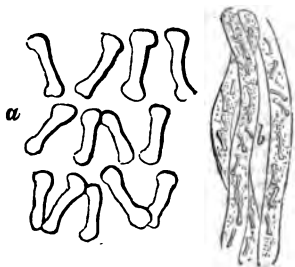


Fig. 82.—Starch cells in the *EUPHORBIA*.
b, floating in the milk vessels.
a, greatly magnified, so as to show their dumb-bell figure.

starch-yielding plant, since, in reference to fresh vegetables, the quantity of starch differs with the season of the year. Thus in the potato the least proportion of starch is found at an early and a later period, and consequently the full-developed potato is the most valuable. Moreover, the state of health of a plant is of moment; for in disease the secretion of starch diminishes. This has been painfully investigated in connexion with the potato blight; and it has been shown that not only does the quantity of starch diminish with the advent of the disease, but cells of another and an injurious nature appear. These new cells are of the lowest order of growth, such as the mushroom, and received the name of the "potato fungus."

The diagrams, 83, 84, and 85, represent this condition; Fig. 83 showing the potato in a healthy and vigorous condition, with the cellular meshwork filled with starch granules; Fig. 84 shows the same cells nearly emptied of their contents; and Fig. 85 the diseased cells occupied by the fungus growth. The inference to be derived from these facts is, that old potatoes are not valuable, and that the diseased parts should be carefully removed.

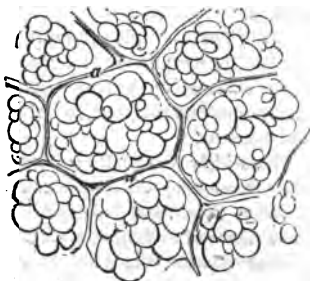


Fig. 83.—Potato in its healthy and mature condition.

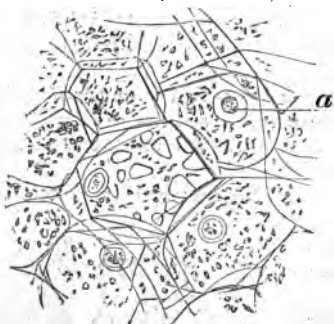


Fig. 84.—A slice of a potato, as it appears after germination, when it is thoroughly withered; or as produced by disease, at the commencement of the "potato disease." The cell-wall remains, but nearly the whole of the starch has been removed. A few grains remain, as shown at *a*.

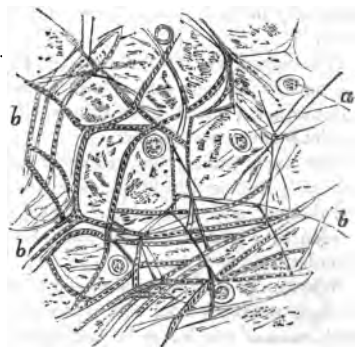


Fig. 85.—Diseased potato, showing the presence of a fungus at *b*, and the isolated grain of starch at *a*.

The ordinary starch of laundresses is oftentimes prepared from potatoes which are not fit for the food of man; but the purest kinds are obtained from rice. It is prepared by simply breaking up the pulp so as to disengage the starch from the cellular meshes; then, by maceration, heat, and motion, to rupture the cell-wall of the granule, and to effect the escape of its contents. Lastly, it is filtered, in order to obtain the starch separate from the membranous cell-wall.

Raphides.—Another secretion found very abundantly in plants is certain crystalline bodies termed *Raphides*, from the resemblance of some of them to a needle (*raphis*). The term, however, is not a happy one; since many varieties of these crystals exist which have no resemblance to a needle. They are not secreted in the form in which we see them, but are deposited from the secretions. They occupy both the cavities of the tissues and the passages which lie between the tissues, but

are the most abundant in the cells of succulent plants. They may be observed with great ease in the stem of the common garden rhubarb (*Rheum*), or of the balsam, and in the bulbs of the onion, and all bulbous garden plants. In the former case they have a square outline, and are isolated (Fig. 87), or they are aggregated into separate star-like bodies (Fig. 88); whilst in the latter they are usually needle-form, and lie in dense bundles (Fig. 86). Their number is so great as to impart a grittiness to rhubarb-root when bitten; and the most so in the finest specimens of Turkey rhubarb. Their chemical composition is that of oxalate, phosphate, tartrate, malate, or citrate of lime, and in size they differ from one-fortieth to one-thousandth of an inch. Phosphate of lime is found abundantly in the bones of the animal body, but not in the precise form in which we observe it in *Raphides*. We have no instance of oxalate of lime crystals in the body; but they are not unfrequently met with in the urine of persons, both in apparent health and in disease; so that it has been inferred that they have been introduced with the food.

Fig. 86.—Rhapides; acicular or needle-shaped crystals, found in the bulb of the Squill (*Scilla mauritanica*).

We do not know the uses of these substances in the vegetable economy; but although they render certain plants brittle, it is not ascertained that they are the result of any diseased action. This brittleness is the best seen in some of the large Cactus plants (Fig. 89).

One which was removed, after a lapse of a thousand years, from the woods of South America to the Royal Gardens at Kew, was wrapped in cotton, and packed as though it were the most fragile of substances.

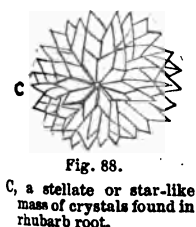


Fig. 88.

C, a stellate or star-like mass of crystals found in rhubarb root.

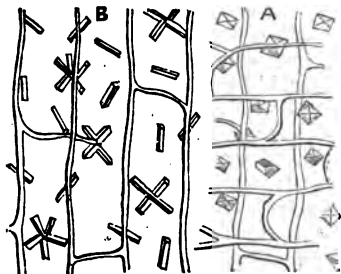


Fig. 87.—Raphides found in the common onion (*Allium*).

A, octohedral. B, prismatic.

They are readily seen on microscopic examination, if a thin section of an onion be placed in water in the usual way; but as they are found in all parts of a plant, from the rough bark (Fig. 90) to the delicate spiral vessels and the pollen, they will be observed in almost every investigation.

They have been produced artificially, and, so far as may be seen, in a state as perfect as those deposited from the vegetable juices. The late eminent botanist, the brother of Professor Quekett, produced the stellate and rhombohedral forms artificially

in cells, but could not produce the needle-shaped crystals. He took a portion of rice-paper, and placed it in lime-water under an air-pump, in order to fill the cells with the fluid. The paper was then removed and dried, and the process repeated until the cells were filled. After this the paper was immersed in weak solutions of oxalic and phosphoric acids, and the crystals appeared at the end of three days (Fig. 91). This, however, is a mere chemical experiment, and has no relation to vegetable tissue,

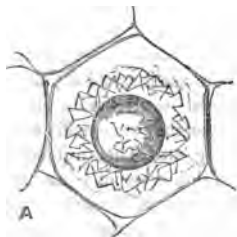


Fig. 89.



Fig. 90.

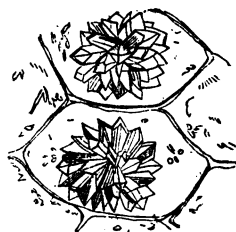


Fig. 91.

Fig. 89.—Raphides. A mass of crystals from the cuticle of a Cactus.

Fig. 90.—Raphides from the bark of the LIME TREE (*Tilia Europaea*), of considerable breadth and prismatic figure.

Fig. 91.—Crystals of oxalate of lime raphides, produced artificially in the cells of rice-paper.

except in so far that a detached morsel of vegetable structure was used as the containing vessel.

Oils and Fats.—The most widely distributed of all vegetable secretions, next to that of starch, is essential and fatty oil, of various degrees of consistence; and, with the exception just referred to, none has so high a value for economic purposes.

There are probably few, if any, plants from which some portion of oil cannot be obtained by distillation; but it is more particularly in the hot climates of India, China, New Holland, Africa, South of Europe, and South America, that they attain their highest degree of perfection, and are found in the greatest abundance. The mustard-seed, for example, which is grown in our climate, yields oil only in a non-remunerative degree; but in the continent of India, with its burning sun, the produce is of great value. So also with the otto or star of roses—an exquisite volatile oil, obtained from the rose-leaf growing in Persia, but scarcely perceptible in our northern climate. This is doubtless due to the chemical influence of the sun's rays, by which all vegetable secretions become highly elaborated.

The oil is most commonly found in the seeds, as in the linseed and rape-seed, of our climate; for as the seed is the product of the plant in its most mature condition, it is the most fitted to be a depository of the most mature secretions. It is, however, found to a great extent in the leaves of plants, as the rose and the peppermint, and in the wood of a comparatively few trees—for example, the Sassafras and the Sandal-wood. The bark is not an unfrequent depository of oil secretions.

A recent discovery made by Mr. Young, of Scotland, has demonstrated the wonderful length of time during which vegetable oils retain their distinctive characters. He has obtained by distillation, at a low red heat, no less than 20 per cent. in weight of

oil from cannel coal. When was that oil first formed? Thousands of years ago; and yet its quality remains so good that it is now compared with sperm oil. Its non-oxidizing property renders it peculiarly fitted for the lubrication of machinery.

As respects the varied social purposes to which it is applied, we may refer to the perfumes of Eau de Cologne and Lavender; the immense quantities of candles and soap which are manufactured in great part from vegetable fats; the oiling of machinery, which is carried to so great an extent, that the London and North Western Railway Company alone use about 50,000 gallons of oil per year; the support of artificial light by lamps; the exhibition of oil for medicinal purposes—as the castor and cocoa-nut oils; and the employment of oil as an article of diet by the inhabitants of all extreme climates. Thus but few articles of commerce can more materially influence the well-being of the community than that under consideration.

It is also worthy of remark how closely the production of oil links together the animal and vegetable kingdoms, not merely in the general chemical and economic characters of the substance, but in its minuter details. Thus we have the fluid oils, as the olive oil, and the semi-fluid, or such as require a higher temperature than that of the air in order to render them fluid, and which closely resemble the fat of animals. There is also vegetable butter, which is largely used in India to adulterate the ghee, or animal butter; and vegetable wax and tallow may, in some sense, rival the like productions from the animal kingdom. There is, however, this remarkable difference—*viz.*, that the fat of animals and of vegetables, each abound in climates the most opposed to each other. The vegetable oils and butters are chiefly derived from the Palm trees of the hottest climates; but the animal oils and fats are met with in greatest abundance where the rigours of a polar clime call for the internal use of such articles of food in order to maintain the animal heat. Thus the fat of animals is, for the most part, employed by the Laplander as food; whilst that of vegetables is chiefly used by the Asiatic and African for external ununction, as a defence from the action of the sun's rays, and as a perfume, which is more than a luxury in the stifling atmosphere of the sunny south. Nature has thus bountifully provided for the wants of man, and in great wisdom has selected, as her depositories, that division of vital existences which is the most abundant in their respective climates. The inhabitants of temperate regions, as of England, find within their own territories only feeble representatives of the products of the two classes; and in order to enjoy them they require to collect the animal oils from the Polar Seas, northern forests, and the banks of Newfoundland, and the vegetable oils from the neighbourhood of the tropics. Commerce, therefore, is to them a necessity.

This branch of trade is as yet in its very infancy, for the Great Exhibition of 1851 has shown that a very large proportion of vegetable oils is unknown to the commerce of the world; and the great effort which has been of late put forth to increase it, has led us to infer that multitudes of vegetable sources yet remain untouched.

We cannot enter largely into this question, but shall now proceed to indicate some of the more ordinary and useful sources of this substance.

Fixed Oils.—*Olive Oil* is produced from the *Olea Europæa*, a shrubby tree, cultivated with great care in Spain and Italy, Syria, and other shores of the Mediterranean Sea. It thrives best in stony ground, and requires a southern clime, in order to perfect the oil contained in the olive berry. The virgin oil is produced by simple pressure of the olives; but that of the inferior qualities is such as is drawn off after the virgin oil has been removed, and which requires heat and water in order to obtain the full quantity remaining. It is mentioned as an article of food in the Sacred writings; and

in eastern and southern climes is almost indispensable to the inhabitants, both as food and for inunction. It is less commonly used in this country than is desirable, since it is highly conducive to health.

Its chemical composition, per cent., is, carbon, 69·38; hydrogen, 13·47; nitrogen, ·058; oxygen, 17·092.

Palm Oil is an article but recently introduced into commerce, and has the great commendation of offering the most effectual means for the suppression of the slave trade. It is obtained from the seeds of various palms, and more particularly from those growing in barbarous states on the western shores of Africa. It is far more consistent than other oils, and approaches to the condition of ordinary fat; so that it is well fitted for the manufacture of candles, and when mixed with sulphur is the most valuable grease for railway carriage wheels. In the countries in which it grows, it constitutes an important article of food; and, from its golden colour and consistence, may be said to be a substitute for butter.

Cocoa-Nut Oil has a relationship to palm oil, inasmuch as it, too, is produced from the palm tree.

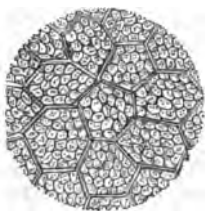


Fig. 93.—Globules of concrete oil, filling the hexagonal cells of the cocoa-nut.



Fig. 92.—COCOA-NUT PALM (*Cocos Nucifera*).

It is a concrete oil, and is found in the cells of the seed of the cocoa-nut before germination. It is likewise obtained by pressure; and is of great value in the production of artificial light. Colonel Rowcroft has shown to us some very excellent candles, prepared in India, from an admixture of wax and cocoa-nut fat. It is also used not unfrequently as an article of food, in the form of butter in India, and of cocoa and chocolate in this country, and has recently been introduced as a medicinal agent in the treatment of consumption.

Its chemical constitution is—carbon, 69·62; hydrogen, 12·49; nitrogen, ·060; oxygen, 17·850 per cent.

Linseed Oil is obtained by pressure, with and without heat, from the seeds of

the flax plant (*Linum*), grown in the British Islands, America, and the Continents of Europe, and of India. It is a common article of food to the serfs of Russia, and is regarded as the highest luxury by the Greenlanders and other inhabitants of polar climes; but it is chiefly used in the arts. It is prepared by distillation for drying, and then is fitted for the preparation of paint. A large proportion of this seed is grown in England and Ireland; but it is chiefly imported from Russia: no less than 482,813 quarters out of a total importation of 626,495 quarters of the seed having been received from that country in the year 1850. It is considered a profitable crop, and is now much cultivated in Ireland. The pressed seeds from which the oil has been partly extracted, constitute the oil-cake, much used in the fattening of cattle.

Rape Oil is in like manner extracted from the rape-seed, which is the product of the *Brassica Napus*, and other species of the cabbage genus of plants. It is considered to be better adapted, when purified, for the lubrication of machinery than any other oil; so much so, that 90 to 100 gallons of it are yearly expended upon each locomotive railway engine. It is also inferior to few, if any, oils in the production of artificial light in lamps. Mr. Brotherton affirms that the English grown seed is to be preferred to that imported from the Continents of Europe and India; and so profitable is the crop, that an acre of land will yield five quarters at 50s. per quarter, or £12 10s. yearly. It is, however, probable that the foreign seed is equally good with the English production, and that the inferior quality of the oil may be attributed to its careless and unskilful preparation. The importation of rape-seed in 1850 was 29,490 quarters.

Turnip-seed Oil (*Brassica rapa*) is very nearly allied to the rape-seed oil, and is much employed in Egypt.

Castor Oil is obtained from the seeds of the *Ricinus communis*, which grows chiefly in the East Indies and the United States of America. It is much used in medicine, but more particularly in the arts, and the manufacture of pomatum. When intended to be used medicinally, it is obtained by pressure without heat, and is then colourless and tasteless, and will so remain for a lengthened period; but that which is employed for other purposes is obtained by heat and pressure, after the first or virgin oil has been removed. This is slightly coloured, and has a rancid odour and taste, and consequently realises but a very inferior price. The seeds do not grow to perfection in our climate. The importation of the oil, in 1849, was 9,681 cwts., of which 9,315 cwts. were obtained from our Indian possessions alone.

Cotton Seed (*Gossypium*) yields a large quantity of oil on pressure; but, on account of the difficulty of removing its colouring and other impure matters it has been hitherto but little used. The seeds are very abundant, and as large as orange seeds, and are either wasted or used as manure and for the fattening of pigs. It is believed that the oil would be of great value if purified; and it could be obtained in any quantity. The seed is chiefly produced in America, Egypt, and India. We have seen immense quantities of it rotting around every cotton plantation we have visited in the Southern States of America.

The Indian corn (*Zea Mays*), or maize, in the State of New York, has been found to contain a valuable oil.

Ground-Nut Oil, obtained from the seed of the *Arachis hypogaea*, is used largely in India, Malacca, and Java, both as food and fuel for lamps. It is a clear, pale yellow oil, and constitutes fully one-half the entire weight of the seed.

Poppy Oil is produced from the seeds of the Opium Poppy, or *Papaver somniferum*, whether grown in this or other countries. It is, however, chiefly produced in India,

since there the plant is scientifically and extensively cultivated by the Honourable East India Company for the opium which it yields. It has many valuable properties, and is a very good substitute for salad oil.

Mustard Oil is expressed from the seeds of the common mustard plant (*Sinapis*), and chiefly in the various parts of India. That our English mustard yields oil, is familiar to the eyes of every housewife who has kept it in paper, or has mixed it with warm water in its preparations for the table.

Croton Oil possesses a powerful medicinal properties, and is procured by pressure from the seeds of the *Narapaula*, and other species of *croton*. It is prepared in India and other eastern countries.

Sesamum Oil, derived from the seeds of the *Sesamum orientale*, and the Ram-til oil, from the seed of the *Guizotia oleifera*, are well known, and greatly valued in India. The seed yields from thirty-four to forty-five per cent. of oil.

Vegetable Butters.—The plants which yield vegetable butters, are (besides the palm oil to which we have referred) chiefly the various species of *Bassia*, all indigenous to India and Western Africa. These oils consist of saccharine matter, spirit, and oil, and therefore are as well adapted for food as for fuel.

The *Epie Oil* is obtained from the seeds of the *Bassia latifolia*, and is common in the Bengal Presidency. It begins to melt at about 70°.

The *Ilpa oil* is expressed from the seed of the *Bassia longifolia* in the Madras Presidency. It is white and solid at ordinary temperatures, and until a heat of 70° or 80° has been produced. It is therefore well fitted for the preparation of both candles and soap.

The *Bassia butyracea* is the plant which yields the purest vegetable butter, and is common on the hill districts in the eastern part of Kemaon, and in the Province of Dotce. It is white and solid at a temperature under 120°, and is so abundant and agreeable that the butter from milk is largely adulterated with it.

Shea butter is obtained from another species of *Bassia*—viz., the *Bassia Parkii*, in Bambara (Western Africa), and at Egga, on the banks of the Niger. It melts at 97°.

Kokum butter is obtained from the seeds of a Mangosteen (*Garcinia purpurea*), and is not only used largely to adulterate butter, but is forwarded to this country to serve the like purpose with genuine bear's grease.

Cacao butter is solid up to 120°, and is the produce of the *Theobroma Cacao*, growing in Trinidad.

Crab, or Carapa oil, from British Guiana, is also another kind of butter derived from the *Carapa guianensis*, but of inferior quality. The natives, in its preparation, boil the kernels, leave them in a heap for a few days, then skim them, and at length beat them into a paste in a wooden mortar. This paste is then spread on an inclined board, and exposed to the heat of the sun, until the butter has trickled into a vessel placed to receive it.

Vegetable Tallow is procured from the tallow tree of Java, known as the *Minyak kawon*, and from trees, probably of the genus *Bassia*, growing in the western countries of the Archipelago.

Piny tallow is another variety produced by the *Vateria indica*, a fast growing plant, common in Malabar and Canara. It is white and solid, and melts at about 97°.

Vegetable tallow differs from oil chiefly in the higher temperature required to render it liquid, and its solidity at the ordinary heat.

Vegetable Wax.—Wax is obtained from a variety of trees growing in similarly hot climates.

Gutta Poda is a wax of a bright-green colour, obtained from *Bifton*.

Myrtle or *Candle-berry* wax, has been made, without admixture, into candles in New Brunswick.

Wax of very good quality has been obtained from trees growing at Shanghai, in China, in Japan, and in St. Domingo; and in connexion with this it may be mentioned that a fungoid growth, found in decayed branches of our English trees, has recently been shown by Professor Quekett to so far resemble wax, that it is not possible to distinguish it by the microscope from the waxy comb of the wasp's nest.

Volatile Oils.—The aromatic and volatile variety of oil is exceedingly extensive, and is largely employed in medicine and perfumery.

Amongst the English specimens we may mention the *peppermint* (*Mentha piperita*), and *spear-mint* (*Mentha viridis*), *lavender* (*Lavandula*), *rosemary* (*Rosmarinus*), *fennel* (*Meum feniculatum*), *thyme* (*Thymus*), from the leaves of all of which essential aromatic oils are procured. The seeds of the *carraway* (*Carum carui*), *aniseed* (*Pimpinella Anisum*), *dill* (*Anethum graveolens*), *coriander* (*Coriandrum sativum*), are well known to yield medicinal aromatic oils on distillation.

It is, however, to hotter climes that we turn for the spices and perfumes which we covet, and especially to the inter-tropical regions.

The *atar of roses* is at the head of this series, and is produced in its highest perfection in Persia, Turkey, the Raapootana States, and other parts of the great Continent of India. The quantity of rose-leaves required to obtain a tea-spoonful of this princely perfume is almost fabulous, and more than accounts for the high price which the oil obtains. It is much adulterated, and chiefly with the oil of geranium, or *Andropogon*.

The *atar of Keova*, derived from the fragrant flowers of the screw-pine (*Pandanus odoratissimus*), and the *jasmine atar*, from the *Jasminum grandiflorum*, and *Sambac*, are favourite perfumes in India. [So also with oil of *aloes wood*, of *saffron*, and of *sandal wood* (*Santalum album*).

Orange flowers (*Citrus*) also yield a most exquisitely scented oil, as may be familiarly observed by walking through the orangeries of this country and of France, when the orange tree is in blossom. It is obtained chiefly from Turkey.

Oil of cloves is obtained from the *Caryophyllum aromaticus*, in India and the Archipelago; and *oil of lemons* from the rind of the fruit of *Citrus Limonum*; and *oil of cinnamon* from the *Cinnamomum zeylanicum*.

Oil of bitter almonds (*Amygdalus amara*) is obtained from the seed, and is highly poisonous. It is produced in Asia.

Cajeputi oil (*Melaleuca*), from India, with oil derived from the *Leptospermum* and the *Eucalyptus piperata*, of Western Australia, in addition to the medical properties of the first, have the power of dissolving India rubber and various resins, and might therefore be used in the manufacture of varnishes.

There are two other vegetable volatile oils, to which we will refer, on account of the favour with which they have long been regarded in India, and are now being viewed in this country.

The *grass oil* is a stimulating aromatic oil, obtained from the seed of the *Andropogon schananthus*, or *Calamus aromaticus*; and the *lemon grass oil*, from other species of the same genus. Both are used to the skin medicinally, and as valued perfumes.

The peculiar odour and great durability of Russian leather is attributed to the employment, during the process of tanning, of a volatile oil obtained by the distillation of birch bark (*Betula*). The oil has a brown or black colour, and after it is dried up, it leaves upon paper the odour peculiar to Russian leather.

Camphor is a substance fitly associated with oils, since it is a volatile oil in a solid state. It is derived from various sources, but the best is the Barus camphor, from Borneo, the product of the *Dryobalanope Camphora*, growing in Sumatra. It is chiefly exported to China, where it realises a price one hundred times greater than that of ordinary camphor. Its flavour is exceedingly fine.

The Dutch camphor, or that obtained by the Dutch from Japan, is prepared by boiling chips of the root and stem with water in an iron vessel, to which an earthen head containing straw is adapted. The camphor is volatilized by the heat, and condenses on the straw. The process is varied somewhat in the preparation of China camphor. The chopped branches are steeped in water, and boiled until the camphor begins to adhere to the stick used in stirring the fluid. The liquid is then strained, and by standing the camphor concretes. It is then sublimed by placing alternate layers of finely-powdered dry earth and camphor in a copper basin, with a similar one inverted luted upon it, and heat applied, until the camphor passes off, and condenses upon the upper vessel.

Gums and Resins.—These two classes of secretions are distinguished from each other by the solubility of gums and insolubility of resins in water, and the solubility of resins and insolubility of gums in alcohol. In some instances the substance is partially soluble in both menstrua; in which case it is called a gum-resin. Each of the classes is used abundantly in the arts, and in medicine; and almost every member of them is obtained from Asia, Africa, and islands of the Southern Sea.

The cheapest gum is that obtained from *roasted starch*, and is used largely in calico-printing.

Gum-arabic, obtained from many species of *Acacia* and other genera, is carefully collected in Turkey, Egypt, Tripoli, and India. It stands at the head of this series in the quantity imported; and amounted to 33,136 cwts. in 1849, from the following sources:—India, 13,687 cwts.; Egypt, 6,232 cwts.; America, 6,064 cwts.; South Africa, 4,876 cwts.; Italy, 664 cwts.; Gibraltar, 460 cwts.; Aden, 397 cwts.; Australia, 372 cwts.; France, 212 cwts.; miscellaneous, 172 cwts. It varies very greatly in quality; and it appears that no very great care is exercised by the collectors in separating the inferior from the better specimens.

Of *gum-senegal* and the *cherry-gum*, or *Tragacantha* (*Astragalus gummifera*), &c., from Syria, there was an importation of 6,577 cwts. and 314 cwts. respectively, in the same year.

Of the resins and oleo-resins, the most abundant are turpentine and lac, both of which are of essential value in the arts.

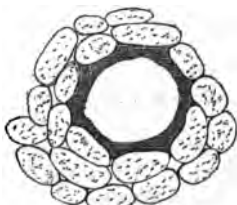


Fig. 94.—Reservoirs of secretions.

Turpentine is obtained from the fir tribe of plants, and chiefly from the *Pinus palustris*, by making incisions into it, and subsequently distilling the exuded secretion. It is found in special vessels in the plant, which were discovered so early as the seventeenth century by the great vegetable anatomist Green, and also in blisters underneath the bark (Fig. 94). It is of the utmost value in its power of dissolving resins, and in mixing and drying paints. The quantity imported in 1849 was 412,042 cwts., nearly the whole of which was from the United States of America.

The distillation of impure turpentine, or turpentine as it is obtained from the tree,

is effected through the medium of water, by which the volatile oil passes over and is collected, and the resin with which it is naturally associated is left behind.

Tar and pitch are also produced from the fir tribe of plants at the same time that the turpentine is collected. The wood is cut into billets, and piled up in a hole made in the ground. It is then covered with turf, or some similar covering, and set on fire. During the slow combustion, the tar runs down the wood, and is collected in the dam prepared in the ground for its reception. This tar contains a portion of turpentine, but may be made from trees which have ceased to emit turpentine on incision.

Pitch is obtained when the tar is distilled; so that an inferior kind of turpentine passes over, and the pitch remains.

Resin results from the distillation of turpentine, or from the drying of the secretion as it exudes from the tree. It is brought to this country in large quantities from the United States, Asia Minor, and other parts of Turkey. It is produced from various species of *Abies* and *Pinus*. Burgundy pitch and frankincense are obtained from another pine, the *Abies excelsa* of the north of Europe, and Canada balsam from the *Abies balsamea*.

Lac is furnished to this country almost exclusively by India, and amounted to 14,786 cwts. in 1849. It is obtained from a great many sources, but chiefly from the *Coccus lacca*, and some of the firs, as the *Ficus Indica* and *Ficus religiosa*, or Banyan tree (Fig. 75). Its varieties are known by the designations of *stick lac*, *seed lac*, *orange* and *ruby shell lac*, *lump* and *buton lac*, *lac dye*, and *white* or *bleached lac*. It is produced by the injuries inflicted upon the young shoots of various trees by an insect, the *coccus lacca*, which feeds upon them. It is employed in the manufacture of varnishes.

It is not possible to name even the great multitude of members of this class, and it must suffice to mention the sources of the following well-known substances:—

Assafœtida is the product of the *Narthax assafœtida*, in India; *benzoin* of the *Styrax benzoin*, in Singapore; *copal* from the *Hymenaea* of Western Africa, *Dammara australis* of New Zealand, and *Trachylobium martinianum* of South America; *dragon's blood* from the *Dracena Draco* of India; (Fig. 95); *gamboge*, from Siam; *myrrh*, from the *Balamodendron myrrha* of Persia, and *yellow gum* from the *Zanthorhæa hastilis* of New Holland.

It is highly probable that the magnificent gum trees of the continent of Australia, which have hitherto been a great inconvenience to the settler in the clearing of his land, will ere long yield gums and resins which will convert them into sources of great wealth.



Fig. 95.—A young plant of the DRACENA DRACO.

A specimen in the island of Teneriffe is above 70 feet high, and 46 feet in circumference at the base, and was known to be very ancient in the year 1406.

Acids.—Various acids are yielded by vegetables, chiefly from their fruit, but very abundantly from the distillation of their wood. Of the former are *citric acid*, from the lemon *Citrus*, the acid juices of the *apple* (malic acid), *pear*, *gooseberry*, and other fruits of our own climate, and the *oxalic acid* from the leaves of the *correl*, or *Oxalis Acetosella*. All these acids appear to have distinct chemical characters, and to require distinct names.

Pyroligneous acid, or wood vinegar, is obtained from the distillation of almost all kinds of wood, and is capable of perfect purification. It is colourless, abundant, and cheap, and has therefore greatly lessened the demand for the coloured vinegar derived from the fermentation of beer or wine, and more particularly in the preparation of such pickles and other substances as would be deteriorated by immersion in coloured fluids. The process is simple—*viz.*, the burning of billets of fast-growing wood, as poplar, in closed iron tubes or kilns, and the separation of the empyreumatic oils, and other impure substances, from the acid. This acid can be obtained in a highly-concentrated state, and is usually sold so that one part is equal in strength to eight of wine vinegar. It is thus a convenient as well as necessary article for the use of persons on ship-board, or for residents in new countries, where vinegar has not hitherto been made.

Gallic acid is obtained from gall-nuts, and *tannic acid* from all sources supplying tannin.

Tannin.—This is the chemical principle which is employed in the tanning of leather, and produces its effect by acting upon the gelatine contained in the skin. It is obtained from a great variety of sources, and not only from the oak bark, as is usually supposed; although it is probable that the excellence of good oak bark, and the ready supply of it afforded by our own country, will ever give it a preference in the estimation of the manufacturer. Notwithstanding the supply of oak bark from our own forests, so large a quantity as 1,200,000 cwts. of tanning materials were imported in 1849; but it must be understood that the tanning principle forms but a small portion of the barks and other materials thus imported. The following are the commercial substances which contain tannin in quantity sufficiently large to render them efficient in the tanning of leather:—

Oak bark, from various species of *Quercus*, but particularly the *Quercus pedunculata*, growing in England and the north of Europe.

Cork-tree bark, from the *Quercus Suber*, imported from Laruche and Rabat.

Valonia, from another oak, the *Quercus Agilops*, flourishing in the Morea, and the south of Europe, and Asia. No less than 333,420 cwts. of this substance was imported in 1849.

Oak-galls, from the *Quercus infectoria* of India and Turkey.

Terra Japonica, *Kutch*, and *Catechu*, extracts from the *Acacia Catechu*, growing in the East Indies. These substances contain a very large quantity of tannin.

Sumach, in powder and in leaves, from Sicily and the south of Europe. It is the product of the *Rhus Coriaria*.

Besides the above principal sources may be mentioned *Kino*, the extract of the *Buchanania latifolia*, of India; *Divi-divi*, of the *Cesalpinia coriaria*, from South America; *mimosa bark*, and bark of the black wattle tree, *Acacia mollissima*; *hemlock bark*, from the fir, *Abies Canadensis*, of the United States of America; the bark of several trees growing in New Zealand; and the *larch bark*, *Pinus larix*, of Scotland.

Opium.—This highly important medicinal substance is procured from the Continent of India, and chiefly from the provinces of Behar, Benares, and other parts of

the Bengal and Agra Presidencies, in our East Indian possessions, and the Independent States of Malawa, and others in the south of India. It is the produce of the white poppy (*Papaver somniferum*), almost exclusively, in our Indian territories; but in the Independent States it is also obtained from the dark-red and other varieties of poppy.

The poppy-seed is sown in the months of October and November, in shallow beds of about seven feet square, and the plant is thence regularly irrigated throughout the season. The capsules (ovaries) are ready for bleeding, or patching, as it termed, about the end of January, when this process commences, and proceeds during the whole of the month of February. It is effected by making incisions into the poppy-head at about four o'clock P.M. daily, and allowing the milky juice to exude and thicken by evaporation upon the capsule during the night. The next day it is scraped off, placed in porous earthen vessels, and allowed to inspissate further. In this crude state, it is carried to the factory, where the drying process is carried on until the opium has attained a certain standard of spissitude, when it then retains from 25 to 30 per cent. of water. It is then made into large round balls, technically termed cakes, each ball being enveloped in a case composed of the petals of the poppy, cemented together by means of thin crude opium in lieu of paste. When the balls have become hard they are ready for the market; forty of them constitute a chest of opium, and weigh about 160 lbs. The produce of one agency, that of Patna, in 1853, was 35,000 chests, or about five and a-half millions of pounds.

The East Indian Company exercise no control whatever over the growth and production of opium in the Independent States, but impose a tax upon it on its exportation to Bombay. In the territories of the Company, however, the government not only watches over its production; but are, in fact, the sole growers of the drug. Any individual growing opium is bound to deliver it to the government agent at a fixed sum per pound; and upon his undertaking to do so, the government makes advances of money from time to time to enable him to prepare the ground, and to plant, irrigate, and gather the crop. In this mode a great many thousands of persons become the servants of the Company,—not by compulsion, but from the greater profit attending upon this, than upon other agricultural produce. The opium thus delivered to the Company is in a crude state, and still requires much attention before it is fitted for the market. No fewer than 1,200 persons are engaged in the Company's factory at Patna alone.

The opium, when packed in chests, is offered to public sale by auction for exportation, and is purchased by dealers of all nations, but chiefly with a view to the supply of the Chinese market. The profit made upon this one Indian production is the most important element in the income of the East Indian Company.

[We are indebted for the above account to Colonel Rowcroft and Dr. James Corbet, both distinguished officers of the E. I. C. Dr. Corbet for some years held an appointment at the Patna opium factory, in the province of Bekar].

Sugar.—Sugar is not exclusively a vegetable production, since it is found abundantly in honey and in milk, both of which are natural animal products, and in the blood and excretions in certain instances of disease. It is, however, chiefly obtained from vegetables, and always so when it is separated from all other substances and made marketable.

Vegetables yield it largely in their fruits, as those of the grape and apple; and many in their sap; but as an article of commerce it is obtained from three sources :

the *sugar-cane* (*Saccharinum officinale*), *beet-root* (*Beta vulgaris*), and the *sugar-maple* (*Acer saccharinum*).

Beet-root alone can be grown in our climate, but not as a remunerative crop for the production of sugar. It is, however, largely cultivated in France, Belgium, Austria, and Prussia; since those countries have no colonies whence they can derive cane sugar.

The *sugar-maple* is also a tree of somewhat northern latitudes, and one of great value to the new settler in Canada and the United States, since it not only yields the sugar which he so much needs, and which in his distant and solitary habitation he could scarcely otherwise obtain, but is valuable as wood also. The sugar is readily obtained by boring holes in the tree, so as to permit the juice to exude, and then causing evaporation of the latter by exposure to the air or by heat.

The quality of sugar derived from the fruits of plants, and also from the beet and the sugar-maple, is much inferior in sweetening powers to that obtained from the next source—the sugar-cane.

The *sugar-cane* is a member of a family which abounds in sugar, and grows readily in low alluvial lands of all southern climes, and especially in the countries bordering upon, or lying within, the tropics. Such are the states bounding the Lower Mississippi, up to about 33° of N. latitude; the West Indian Islands; the East Indies; the Mauritius, and parts of China. The cultivation requires a large capital and the employment of a great number of hands; so that, with the exception of the Indian crop, it is the product of slave labour. The plants are set at regular intervals, and grow luxuriantly with a single stalk and large waving leaves (Fig. 96), to the height of ten or twelve feet; so that a sugar plantation, with its well-cultivated fields, large red boiling-house, planter's mansion, and village of negro huts, is a picturesque scene. It is also a busy scene during the period of cultivation, but more particularly at that of boiling, when the process is not stayed night or day until it is finished. We have inspected many, and have been struck with the air of richness and wealth which usually pervades them.

When the plant is mature it is cut down near to the root, and carried in wagon loads to the boiling-house, where it is crushed between powerful rollers, impelled by steam,



Fig. 96.—THE SUGAR-CANE (*Saccharinum officinale*).

until the juice has been thoroughly extracted. The juice, mixed with quicklime, is then transferred to large boilers, where it is evaporated, and afterwards set aside to crystallize. The larger portion of the sugar is thus separated from the fluids in which it was secreted; but a considerable quantity remains uncrystallized in the mother-liquor, and constitutes the molasses so abundantly used in those climates as food, and for the distillation of rum. The colour of the sugar is more or less brown, and is purified either in this country or in the country of its production, by filtration through animal charcoal. Bullock's blood was formerly used for this purpose. The coloured uncrystallized liquor which then remains is the treacle of commerce.

We may mention that, as a curiosity, some cane sugar was made from sugar-cane grown in this country, and exhibited at the Great Exhibition of 1851.

Good specimens of *grape sugar* were forwarded to the Great Exhibition from Tunis and the Zollverein States. *Palm sugars* have hitherto been mere curiosities, but they have been made from the date palm of the Deccan, the Gomutus palm (*Arenga saccharifera*) of Java, the Nipa palm stem, and the flower of the *Bassia latifolia*, and might, doubtless, be procured from all palms yielding refreshing and fermenting juices.

Colouring Principles.—The colours presented by plants are exceedingly varied, and all alike depend upon the presence of colouring principles in the cells of colourless tissue.

There are eight principal colours recognised in vegetables—*viz.*, white, gray, brown, yellow, green, blue, red, and black; and each of these has many distinct shades.

Of these shades of colour, nine have been associated with *white*: pure, snow, ivory, chalk, and milk white; with silvery, whitish, turning white, and whitened.†

A similar number is also attributed to *gray*, and are designated ash, lead, slate, and pearl gray; smoky, hoary, and rather hoary, and mouse-coloured.

Twelve have been computed in connexion with *brown*; *viz.*, brown, chestnut, deep and bright brown, rusty, red, brown, rufous and cinnamon-coloured, with lurid, sooty and liver-coloured.

Yellow has twenty shades; thus, lemon, yellow, golden, pale, leather, waxy, and Isabella yellow; sulphur, straw, ocre, orange, apricot and saffron-coloured; testaceous, tawny, and livid.

There are seven varieties of *green*, of the shades of olive, grass, sea, yellowish, apple, meadow, and leek.

Red has seventeen shades: carmine, rosy, purple, sanguine, scarlet, cumaba, vermilion, coppery, brick, flame-coloured, &c.; whilst its compound *blue* has but seven—*viz.*, prussian, blue, indigo, lavender, violet, lilac, and sky blue; and *black* has four: pure, coal, raven, and pitch black.

Thus as many as eighty-six different shades of colour have been determined to exist in plants; but only two chemical colouring principles have been discovered—*viz.*, chlorophyl and chromule.

Chlorophyl is so called from its imparting a green colour to plants; that is, that kind of green which is universally met with in all plants growing in the light. It is distributed to the tissues themselves, but more particularly to the surface of the starch cells, which are abundant in all green plants.

Chromule is the general term for the colouring principle of all other colours, although they may be so closely approximated that adjoining cells may have totally different colours.

Dyes.—Another highly important series of vegetable secretions are such colouring

matters as are capable of being used as dyes of textile fabrics. These are very varied, and are also chiefly found in southern countries. This series comprehends nearly all the known dyes, since but few (as the cochineal insect) belong either to the animal or mineral kingdom. The chief substances are

Indigo, of which no less a quantity than 70,482 cwts. were imported in 1850. It is the product of the leaves of the *Indigofera tinctoria*, and *I. anil*, growing in the low districts of India and South America. It is a fast dye, if in the process of dyeing it be first deoxidized, but otherwise it is not permanent. It yields the Indigo colour, and also a green when mixed with yellow.

Madder is one of the most useful and common dyes, and is derived from the root of the *Rubia tinctoria*. Its home is Naples, France, and the North of Europe. 2,985 tons were imported for this purpose in 1850. It forms one of the most permanent dyes, and constitutes the Turkey red dye, so celebrated for its brilliancy. Garancine is the red principle of madder, obtained by the action of sulphuric acid. 2,985 tons of this substance were imported from France in 1850.

Logwood is the wood of the *Hamatocylon campechianum*, found in the Bays of Campeachy, and Honduras, in Central America. Its value is sufficiently great to cause the right cutting it to be the subject of a treaty between this country and the States in which it grows. Its colour is red, but black when precipitated with iron, purple with tin and alum, and brown with copper. 3,500 tons were imported in 1850.

Brazil wood, from the *Cassipina brasiliensis*, is one of the largest importations of dye woods. 3,120 tons were imported in 1850.

Amongst the remaining dyes are *alkanet root*, from the *Anchusa tinctoria*, grown in Asia and the North of Europe; *Nut-galls*, an excrescence on an oak, the *Quercus infectoria*, in Turkey; *Safflower*, produced in Southern Asia, Egypt, and the Levant, from the dried flowers of the *Carthamus tinctoria*; *Annatto*, a South American orange-colouring matter, from the seed of the *Bixa orellana*; *Turneric*, from the root of a cucumber, the *Circuma longa* of India; *Peach wood*, or *Nicaragua wood*, of the *Cassipina*, from South America; *Fustic*, the wood of the *Rhus cotinus* of Cuba; *Camwood*, from the *Baphil nitida* of Sierra Leone; *Quercitron bark* of South America, from another oak, the *Quercus tinctoria*; the *alder bark* of this country, from the *Alnus glutinosa*; *Catechu*, an extract of the wood of the Indian *Acacia Catechu*; *red sanders*, from the *Pterocarpus santalinus* of India; the *Persian berries*, from the *Rhamnus infectoria* of the Levant; and many others of less note.

It is worthy of remark, that the lowly-organised Cryptogamic cellular plants, or lichens, afford colouring matters in great abundance, under the designations of *Orchall* and *Cudbear*. The following are the chief: *Ramalina furfuracea*, from Angola; *Rocella fuciformis*, from Mauritius, Madagascar, Lima, and Valparaiso; *Rocella tinctoria*, from the Cape de Verd Islands; *Parmelia perlata*, from the Canaries; with the *Parmelia tartarea*, *Umbilicaria pustulata*, and *Gyrophora murina*, of Sweden.

We have purposely avoided the chemical questions which naturally arise when considering the interesting and important vegetable products which have been passed in review; but we cannot omit to state here, that, although the widely-distributed substances—starch, sugar, and gum—are apparently so very diverse in their external characters and general properties, they have very close chemical relation. Indeed, so closely are they associated that they are daily and hourly converted in the living plants, the one into the other, in the order in which we have placed them—viz., starch

sugar, gum. In the early stages of development, the major product is starch; but, as maturity approaches, this is gradually changed to sugar; and to gum when the period of decay ensues, or the starch at once passes into the state of gum. So in the malting of barley: the object there is to convert the starch into sugar; but if the process of germination be carried a little too far, the sugar begins to disappear, and is supplanted by gum. The prolonged cookery of any farinaceous substance has always this tendency; so that biscuits not unfrequently contain a portion of gum, difficult of digestion, with the starch which is capable of ready conversion into the material of the blood.

Silica.—The last secretion to which we shall now refer, is one of peculiar interest—viz., silica, or flint. This is a mineral substance; and, apart from vegetable structures, is so indestructible that the strongest chemical acid is required for its solution, and yet it has structures so delicate that a stem of wheat can dissolve it with facility. It is not pretended that vegetables have the power of producing flint, but only that they are enabled to dissolve it in their juices, when water and other fluids alone cannot dissolve it. This power seems to reside at the extremities of the rootlets, for it is impossible that flint could be taken into their delicate tissues until it has been dissolved. The sources of silica or flint, are—

1. The sand which is so largely met with in almost all kinds of soil, and which has the further valuable property of permitting the rain to percolate to the roots of the plant. Its composition is chiefly that of silica, as may be familiarly inferred from its essential presence in the manufacture of glass.

2. From the flint nodules which are found in the chalk formations, and which themselves are the productions of long-buried sponges, mosses, and minute animalcules.

3. From the skeletons of animalcules which still remain in the soil. These skeletons are composed of flint, as may be proved from their non-solubility in boiling nitric acid (Fig. 97). So numerous are they that Richmond, in Virginia, United States, is built upon a stratum eighteen feet deep, and upwards of thirty miles in length; a stratum representing an innumerable number of animalcules, when it is borne in mind that each animalcule is almost too small to be seen by the naked eye. Similar deposits also exist in the old world.

These skeletons are also found in other positions. Thus guano, a substance consisting of the excrements of birds, contains vast numbers, chiefly of three genera, *Actinocyclus*, *Gallionella* (Fig. 97), and *Coscinodiscus*. A powdery substance is known in Germany as *Berg Mehl*, or mountain meal, which is chiefly composed of them. This is the produce of the strata through which the mountain torrents run, and is brought down by the waters. From its resemblance to flour, it is used in certain localities as an article of diet.

4. From the remains of plants in the form of manure, or otherwise, which contain silica; as, for example, the wheat straw.

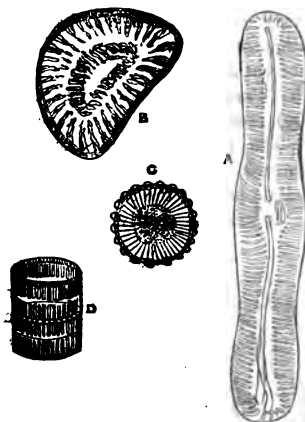


Fig. 97.—Silicious skeletons of the *Diatomaceae*, which have been boiled in nitric acid. A, *Navicula grandis*. B, *Campylodiscus clypeus*, both found in guano. C and D, *Gallionella sulcata*, both from the silicious soil in Virginia, U. S.

* The parts of plants in which the silica is chiefly found, are the external layers of the cuticle, as in the shining straws of our corn fields, and the canes and bamboos of hotter climates; and certain rough straws, as that of the *Equisetum hyemale*, which is so rough as to be used in the polishing of metals. It is also found in the interior of the joints of certain bamboos, and then is termed *tabasheer*, and from its rarity commands a high price. It is also found in the hard grains themselves, as of wheat and oats, and more particularly of the rice; from which cause the Caribs, the Malays, the South Australians, and other savage nations have their teeth ground down by the trituration of the uncooked grain.

The layer is exceedingly thin, but yet it is one of pure flint, as may be proved by its non-solubility in boiling nitric acid. It overlays the vegetable tissue, and assumes its form, and therefore varies greatly in appearance,

Fig. 98.—Siliceous cuticle from the husk of the wheat (*Triticum*), showing cups for the insertion of hairs, and also spiral vessels.

according to the object examined.

In Fig. 98 we have an illustration of its appearance in the common wheat. From this siliceous coating the flinty hairs of the oat are formed; and it is well known that animals living much on oats are liable to intestinal accumulations of these indigestible hairs; and in a lesser degree men eating oatmeal are liable to a like inconvenience. The common meadow grass (*Festuca pratensis*, Fig. 100), presents a siliceous coating of considerable beauty.

The most beautiful examples are the *Equisetum hyemale*, the *Pharus cristatus* (Fig. 101), the common rice (*Oryza sativa*), and the stellate hairs of the *Deutzia scabra* (Fig. 102):

It must be clearly understood that this substance constitutes no part of vegetable

structure, neither does it assume any form of organization, its sole and most important duty being to give strength to the slender stem, and to protect the delicate tissues from atmospheric influences.

That the quantity required to supply the wants of a field of corn is very considerable,

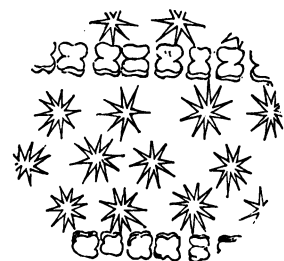


Fig. 101.—Silica in square and star-like masses on the leaf of a foreign grass, the *Pharus cristatus*.

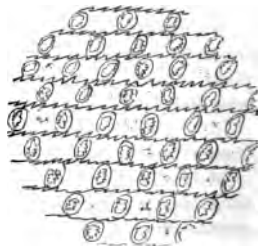


Fig. 100.—Cups of Silica on the chaff or palea of the common meadow grass (*Festuca pratensis*.)



Fig. 102.—Sinuous cells and stellate flinty hairs on the leaf of the *Deutzia scabra*.

may be proved from the following table; and the more

so, when it is remembered that the layer is so thin that it cannot be removed without detaching also a portion of the vegetable tissue.

Proportion of Silica, or flint, in 1000 parts of the ashes left after burning the following vegetable substances.

Oat straw	.	.	.	.	.	45
Barley	.	.	.	.	.	38.5
Wheat	.	.	.	.	.	28.7
Indian corn	.	.	.	.	.	27
Oak leaves	.	.	.	.	.	15
Ferns	.	.	.	.	.	10.4
Pea straw	.	.	.	.	.	10
Potato tops	.	.	.	.	.	8
Heath	.	.	.	.	.	5.8
Beans	.	.	.	.	.	2.2
Bean straw	.	.	.	.	.	2
Cabbage	.	.	.	.	.	2.1
Buck wheat	.	.	.	.	.	1.0

This subject has an important bearing upon the rotation of crops, for it is manifest that if successive crops of corn, and especially of oats, be obtained from the same land, there must be an enormous expenditure of this necessary article; but that a much less quantity suffices, if potatoes, pease, beans, or cabbage be given as intermediate crops. So, also, with regard to manures. It is clear that a manure must not only contain the carbon which forms the straw, and the salts which are always found with it, but there must be a constant and abundant supply of silica. This is effected by using corn, and especially oat straw, as manure, and also by the use of guano, which contains a large per centage of silicious skeletons.

THE ORGANS OF PLANTS.

Having now considered, in such detail as our space has permitted, the various elementary tissues which have been discovered in vegetables, and the juices and secretions which they contain, we proceed to describe the parts or organs which are formed by their combination. Such are the leaves, flowers, and fruit, and the structures which support them.

The modes in which we might proceed are numerous, and partly arbitrary, varying with the fancy of each author; for no one arrangement of the organs of plants is found in Nature which is acknowledged by all investigators to be more natural than any other.

The nearest approach to Nature will be found in proceeding either centripetally or centrifugally: that is, either first to describe the seed, and thence pass to the centre of the stem, through the fruit, flowers, leaves, and other appendages to the stem; or to commence at the stem and roots, and then clothe these organs with leaves, flowers, and fruit, in the order which nature has selected. Of these two we prefer the latter course, and shall proceed to describe the stem, with its root, and the various organs supported by them.

The Stem.—In all flowering plants the stem proceeds from the seed and that part of it termed the plumule; whilst, at the same time, the root is developed from another part of the same seed—*viz.*, the radicle. These two newly-formed organs thence assume diverse directions, the root passing downwards to fix the plant firmly to the earth, and to abstract nutriment from the ground; whilst the stem usually emerges from the soil, and grows in a perpendicular direction, so as to bear the leaves and other organs of growth and reproduction from the ground, and expose them freely to the action of the light, air, and moisture. The point in the seed whence the stem and root diverge is known as the collum or neck (Fig. 100 *b*), and even in trees which attain to a considerable size this line remains more or less distinct.

When the seed has begun to germinate, and the growing points just referred to have lengthened, the other parts of the seed—*viz.*, the cotyledons, or seed-leaves, enlarge, and take on the function of nutrition by converting the starch contained within them into sugar. At length, by their elongation, they emerge from the soil, and appear as two

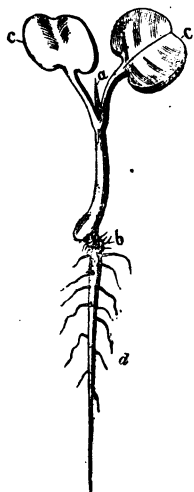


Fig. 103.—Exhibiting the parts of a plant soon after the commencement of germination. *c*, the cotyledons, or seed-leaves, which have appeared above the ground.

a, the plumula, or growing point of the stem, elongated between the cotyledons.

b, the collum, separating (or rather connecting) the part of the plant above it, the ascending axis, from the part below it, the descending axis.

d, the radicle, with the rootlets proceeding from it.

opposite roundish leaves, which are capable of absorbing oxygen from the air, and fixing carbon within the tissues which are then in process of formation. At this stage, then, we find a root, stem, collum, and seed-leaves, all of which are represented in Fig. 103.

The current of sap having been set in motion by the action of the cotyledons, or seed-leaves, the latter disappears, and the plumule, or young stem, continues to elongate rapidly, and until it arrives at the point whence its first leaf is to issue, is technically termed a *node*. At this point the stem swells, and the structures of which it is composed are bent out of their former direction, and, in part, enter within the structure of the newly-developed leaf. The stem may now fairly take on the term of *ascending axis*, which is usually given to it, since it has begun to develop the organs which are subsequently to be arranged around it as their centre. It has also received a variety of other names, which it may be useful to mention—*viz.*, the *caudex intermedius* and *ascendens*, *truncus* or *truncus ascendens*, with *culmus* and *stipes*. All these have a similar signification.

The growth is not arrested by the development of a node and leaf, but proceeds for a certain period, until another leaf and node are formed; and so on progressively until the period of growth has passed away. We have then a series of nodes and spaces between them, which spaces are termed *internodes*. A stem may thus be said to consist of a number of nodes, with their internodes.

Nodes.—These are well seen in all grasses, as the ordinary grass of this country; with wheat, oats, and other grasses; and more particularly in the bamboos and canes of southern climes. It is there found as a distinct bulging

around the stem, of a hard and rounded character, and oftentimes bending the stem from the perpendicular direction. In wooded plants, or trees, in general, it is less per-

ceptible, since the small swelling at the base of the single leaf which is there developed, bears but little proportion to the size of the trunk of the tree.

The essential difference in structure between a node and an internode is, that the bundles of wood are compressed and turned aside in the former, so as to enter the leaf, and thus a slight interruption to the course of the general circulation ensues; whilst, in the internode, the bundles of woody fibre pass perpendicularly, and lie parallel to each other. In some instances, as in the grasses with hollow stems above mentioned, this compression or contraction of parts is so great, that a septum is formed across the stem, dividing it into two or more cavities. This may readily be seen on making a perpendicular section of a stalk of wheat, or of the bamboo, and with the septum of the latter may sometimes be found the flinty deposit before mentioned, under the term of *tabassheer*. They are then said to be *closed*, in opposition to the *pervious* or open condition, found when the pith passes through it. When the node surrounds the stem, as in the grasses and the hemlock, it is designated as *entire*; and when otherwise, as in trees, it is termed *divided*.

As the essential element of a node is a new disposition of the woody and other tissues, to meet the requirements of a leaf, it is manifest that wherever a node exists there must be, or have been, a leaf, perfectly or incompletely developed. In many instances the growing process ends after the formation of a node and before the entire development of a leaf; and then will be formed a leaf-bud, immediately above the base of a leaf. When such leaf-bud is evident, the node is termed *compound*; and when otherwise it is called *simple*.

So far this account may suffice for both herbaceous and woody stems, but it is needful here to interrupt our description, and consider herbaceous and woody stems separately. This results from the great difference which is observed in the structure, as well as in the degree of delicacy of organization of the two kinds of stems.

Stems of Herbaceous Plants.—Herbaceous plants are, for the most part, annuals—that is, such as are produced and die in the same season. It is, therefore, not

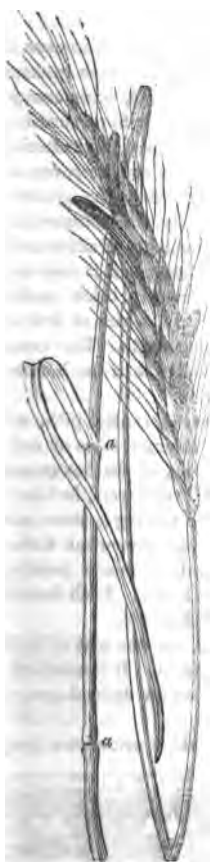


Fig. 104.—A stem of the family of grasses, showing at *a a* the enlargements indicating the existence of nodes.

The interval between the two nodes is termed an internode.



Fig. 105.—Diagram, showing at *a a* the nodes, with bundles of woody fibre passing from their parallel course in the stem to enter the leaf bud or the foot stalk of a leaf.

necessary that they should possess the rudeness and strength of texture which appropriately belong to plants that have to combat the power of the elements through a long series of years.

The stem, for the most part, is small, seldom attaining to a greater diameter than one and a-half inch; and, with the exception of twining plants, and such grasses as the bamboo, do not exceed six feet in height. The structure is delicate, being composed of cellular tissue of a somewhat loose kind, with bundles of woody fibre running at intervals from the root upwards. They are thus but ill-fitted to resist the influence of strong winds, or the destructive propensities of animals. There are, however, some circumstances which tend to increase their strength. Such are—first, the cylindrical form of the stem; secondly, the hollowness of the stem; and, thirdly, the inclosure of the stem by a tough cuticle or bark, and, in some instances, a further layer of silica or flint. That the cylindrical form is stronger than any other is well known; but it may not be so commonly understood that a hollow cylinder, with moderately thick walls, is stronger than a solid rod of the same material. Thus that vacuity, which at first sight is indicative of weakness, is really fitted to impart increased strength. The cause of the hollowness is the more rapid development of the perpendicular than the horizontal layers of the stem.

The stem of an herbaceous plant thus consists of three parts:—a central pith, which is frequently wanting; an external envelope or skin; and an internal mass of cellular tissue and woody fibre. The *pith* is composed of cellular tissue, of the hexagonal or octagonal form. The *woody fibre* of the stem is not found in even layers, but in bundles lying detached from each other, as may be readily seen by tearing a stem across, when the bundles of tough fibres will be stretched, and project somewhat from the broken surface. It may also be seen through the cuticle of the common parsley, in ribs passing in parallel lines from the root upwards into the leaves. Each bundle is usually inclosed in a mass of cellular tissue, to which it gives firmness.

Cuticle.—The cuticle of herbs is an interesting structure, and the seat of a large part of the respiration and digestion which proceeds in those plants. It consists of two layers—an epidermis or scarf-skin, and a true skin, with certain appendages—*viz.*, stomata, hairs, prickles, warts, and reservoirs of secretions.

The *Epidermis* is a layer of inspissated organic mucus, which sometimes may be readily detached from the cuticle, as in the common box-leaf, but at others requires maceration in water for some time before its existence can be demonstrated. It covers all the external surface of the plant, except the stomata and the free end of the stigma, and it even forms a covering for the hairs. Mohl considers it to be a secretion poured out from the external surface of the cells, the walls of the cells themselves being at the same time thickened by internal deposits. It is not a cellular structure, although, when removed from the surface of the cuticle, it has a cellular outline; but is a simple layer, with markings corresponding to

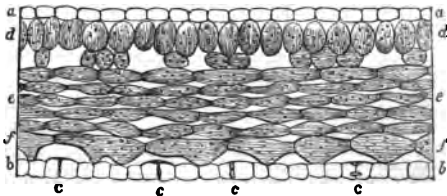


Fig 106.—Showing the structure of the leaf in the lily on a transverse section.

- a, b, outer layer of the cuticle, composed of compressed cells.
- d, a subjacent layer of larger cells, with vacuities, or parenchymatous structure, underneath.
- e, canals of climater passing through the cuticle to the air cavities above.

the cell-walls over which it is placed. Hartig has divided it into three layers—an internal, an external, and an intermediate layer; but such is not the experience of other observers. Its use is to protect the delicate structures lying beneath it, and is analogous to the scarf-skin which protects the skin of man.

The *True Cuticle* is composed of one or more layers of cells, the outer one being much flattened (Fig. 106 *a*). The cells are mostly of hexagonal figure and wavy outline. Some anatomists have denied the cellular nature of this structure, on the grounds that the cells are not demonstrable, and that the skin may readily be peeled from the subjacent tissue; but this theory is not usually admitted. Moreover, in the cactuses and orchids, and also in the *Nerium Oleander*, there are several layers of cuticular cells, the whole of which may be demonstrated (Figs. 106 *d*, and 110).

Whenever any shred of cutis is removed from the stem of a herb, some portions of woody fibre are removed with it, so that it may be questioned if woody tissue is not a component of the skin; but it is perhaps more correct to associate the wood with the structures immediately beneath the skin rather than with the cellular skin itself.

Stomata (Fig. 107) are mouths by which respiration and exhalation are carried on in vegetables. They constitute openings into and channels through the epidermis, and lead into cavities beneath (Fig. 108, *A*). Their structure is somewhat complicated, since, for the most part, there are a series of rounded cells bounding the opening, with two larger kidney-

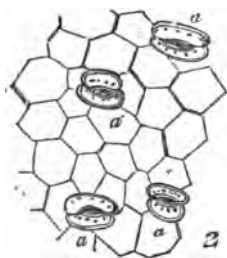


Fig. 107.—Exhibiting a front view of four stomata *a*, imbedded in hexagonal cellular tissue.

shaped cells in the centre, pressing closely against each other when the stomate is closed, and cemented to the surrounding cells by something in the nature of a hinge, which permits them to rise and fall with considerable force (Fig. 108, *C a*). In the centre of the stomate there is a raised line when it is closed, and a slit when it is open (Fig. 108, *C c*); and through this opening an entrance is effected to the cavity beneath (Fig. 108, *A c*). This cavity varies in figure and form; but it is always surrounded by cells,

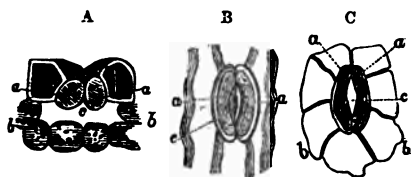


Fig. 108.

A, stomata of the *Iris*. *a a*, green cells bounding the orifice. *b b*, cells of the parenchyma. *c*, air chamber. *B*, the same as seen from above. *a a*, cells of the stomata. *c*, opening between them. *C*, stomata of the apple leaf. *a*, cells of the stomata. *b b*, cells of the cuticle. *c*, opening of the stoma.

which communicate freely with other cells of the epidermis (Fig. 108, *A*). It is thus that air and moisture, having entered by the stomata, act not only in the cavity beneath that organ, but in the surrounding open cellular net-work of the leaves or cuticle.

Such is a general description of the stomata; and before entering further into detail we will request our readers to verify the above account by an examination of these structures. Take a very thin slice from the under surface of a leaf or flower of any plant, as of the lily (Fig. 109, *A*), the *Zea Mays* (Fig. 109, *B*), or the common geranium; or strip a thin piece of the cuticle of a herb, as of the parsley, and place it in water between two pieces of glass, and examine it with the microscope. First examine the outer surface, on which may be seen the cells and slit referred to, and then turn over

the object, and carefully notice the cavity into which the slit is directed. The minute and regular arrangement of the various parts of each stomate, and of all the stomata on

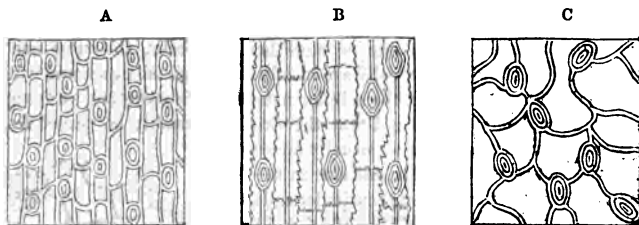


Fig. 199.—View of ordinary stomata, as seen between the veins of the leaf of the LILY, A, or, ZEA MAYS, B, both endogenous plants, and of an exogenous plant at C.

Their regularity in figure and position, and the uniformly oval outline, will be observed.

the cuticle, will excite admiration; and the more so when, on examining a variety of plants, the little organ is found very variously figured.

The general outline of the stomate is commonly circular or oval; but in the flax plant, the *Agave Americana* (Fig. 61), and a somewhat similar one, the *Yucca gloriosa*, it is quadrangular. In *Marchantia* they resemble funnels, and are composed of several cells arranged in tiers, and forming tubes, which perforate the epidermis, and terminate in the cavity beneath. In the oleander (*Nerium Oleander*) the cells have disappeared, and the cavity is simply protected by hairs. This may readily be seen, if a portion of the leaf be placed under the microscope, as above directed. The *Myrodon, punctulatum*, growing on trees in the antarctic regions, has a remarkable modification of the stomata. Dr. Hooker states that the stomate expands on both sides into a kind of cup—a condition which results from the hour-glass construction which is met with at the aperture.

But whatever may be the figure of the organ it is so uniform in the same species that certain botanists, as Brown, are of opinion that they might be made a basis of classification. This, however, would be very difficult, on account of their minute size and the necessity for the constant use of the microscope; and further, from the fact that a few plants present more than one form of stomate. Thus, in the *Nepenthes* or pitcher plant, there are two forms of stomata, one being semi-transparent and nearly colourless, of an oblong figure, and with pellucid globules within the cells whilst the other is roundish, red, and more opaque, and rests not over a cavity, but upon a gland.

It is proper to state that certain observers of eminence have denied the accuracy of the above statement, as to the construction of stomata, and have affirmed that they do not lead into a subjacent cavity, and consequently have no opening at the slit. Some German anatomists have affirmed that the supposed opening is simply a thinner translucent portion of the membrane, and that the slit is the thickened border of this space. Brown believed them to be usually imperforate, and to be formed by an opaque and sometimes coloured membrane. Such, however, is not the opinion commonly entertained; and we may confidently appeal to the investigations of our readers to refute it.

Stomata are not found upon all plants, the exceptions being such as are submersed

in water, or grow in darkness, and also the lowest classes of plants, as mushrooms, seaweeds, and lichens, except mosses. Neither are they found upon all parts of any plant, but are absent from the roots and ribs of leaves. They are most abundantly found on

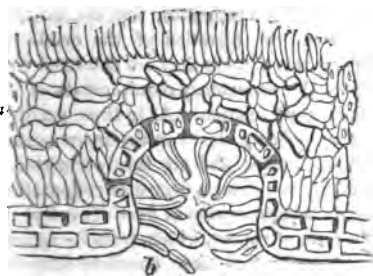


Fig. 110.

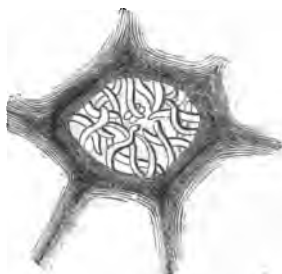


Fig. 111.

Fig. 110.—A side view of the modified stomata of the *NERIU M OLEANDER*, and of a *BANKSIA*, in which they are seen clustered together at the bottom of a pit, *a*, the entrance of which is defended by hairs, *b*.

Fig. 111.—A front view of the same organ.

the under surface of such leaves as present one surface to the soil (Fig. 106), but on both surfaces equally, if the edges only be directed vertically. They are also met with on the cuticle of stems, on flowers, and even on the seeds of a few plants, and on their cotyledons.

The number of stomata found upon a moderate-sized leaf is sometimes prodigious, amounting in some instances to 160,000 on each square inch of surface. Thomson gives the following enumeration, which shows not only the total number but the relative quantity on the two surfaces of the leaf:—

	On each square inch	
	of upper side,	and of under side.
<i>Alisma Plantago</i> (Water plantain)	12,000	6,000
<i>Cobaea scandens</i>	none.	20,000
<i>Dianthus Caryophyllus</i> (Pink)	38,500	38,500
<i>Daphne Mezereum</i> (Mezereum)	none.	4,000
<i>Hypericum Grandiflorum</i> (St. John's Wort)	none.	47,800
<i>Ilex</i> (Holly)	none.	63,600
<i>Iris Germanica</i> (Iris)	11,572	11,572
<i>Olea Europaea</i> (Olive)	none.	57,600
<i>Pæonia</i> (Pæony)	none.	13,790
<i>Pyrus</i> (Pear)	none.	24,000
<i>Rumex Acetosa</i> (common Sorrel)	11,088	20,000
<i>Tussilago Farfara</i> (Coltsfoot)	1,200	12,500
<i>Vitis vinifera</i> (Vine)	none.	13,600
<i>Viscum album</i> (Mistletoe)	200	200
<i>Syringa vulgaris</i>	none.	160,000

Of 28 plants in this table which had been examined, 15, or more than half, had no

stomata on the upper surface; 6 had fewer stomata on the upper than on the under surface; and 5 had an equal number on both surfaces,—leaving only two instances in which the number was greater on the upper than on the under surface of the leaf.

The number and position of the stomata must have an immediate reference to their function. It is commonly understood, as has already been intimated, that the function is that of admitting air and moisture to promote the digestion of the crude sap which had been brought to the leaves, and that for this purpose they are endowed with the faculty of opening and closing according to the momentary requirements of the plant. This will explain the necessity for their conformation. As to their position, that seems to be due to several causes. First, that by being placed on the under surface they are shaded from the direct action of the sun's rays, and are thus permitted to carry on their functions without being impeded by too great a degree of evaporation. Secondly, they are also more sheltered from the injurious deposition of dust. Thirdly, the exhalation of moisture from the ground is in the form of vapour, which, from its specific gravity, rises, and thus reaches and enters the under surface more certainly than the upper surface. It is not presumed that in any case water enters the stomates as such, but only in the state of vapour; for although plants are refreshed after a shower, it does not follow that the rain was bodily introduced within them; and it seems inconceivable that bodies of so minute a size should at the same time be fitted for the admission of gases, and of fluids of such density as water.

There are those, however, who maintain that such is not the function of the stomata, but that they are in the nature of glands. Link says that he cannot find a distinct connexion between the stomata and the subjacent cavities in the cellular tissue of the leaves. Moreover, he cannot understand how organs of so distinct a structure should only lead to mere cavities in the cellular structure; and the obstructing and covering matters which they produce have always led him to consider them as organs of secretion. Brown also affirms that they are rather of the nature of glands; but there cannot be a doubt that in the vast majority of instances this view is incorrect. It is true that in a few instances the stomata are modified both in figure and in function to perform the office of glands. Such is the case in the *Dionaea Muscipula*, or Venus' fly-trap (Fig. 1), in which the stomata are reduced each to a pair of parallel green cells, which are placed upon the surface of the leaf, and secrete a tenacious mucus; but such are exceptional cases.

It would be interesting if we could determine with certainty the precise mode in which these beautiful organs are formed; but such seems hitherto to have been a hopeless task. Mohl sought to determine it by examining the different parts of a growing hyacinth, in the expectation that the parts of the leaf, which are successively developed from above downwards, would have stomata of various degrees of perfection. He noticed that in the lower part of the leaves, or that most recently developed, small quadrangular cells, with a slit of about equal diameter either way, were placed between the layers of the epidermis. These sometimes contained a granular substance, which, higher up in the leaf, became a compact mass. At the same period a partition was formed in the middle of the cell, at first slightly, but subsequently more strongly marked, and at length unfolded, so that the simple cell became divided, and a stomate was formed. After this the surrounding cells enlarged, and the central slit increased at a still greater rate. All this and the subsequent completion of the stomate may be observed by any of our readers who may have a tolerable microscope, and will obtain by practice a certain delicacy in cutting minute structures.

Hairs are minute, semi-transparent, transparent, or opaque thread-like processes, attached to the cuticle by one extremity, and remaining free at the other (Fig. 112). They are always of a cellular character, the cells, if more than one, being larger and more numerous at the bottom, and then piled one upon the other, and laid in one or more rows, until the apex is attained, with its single elongated, rounded, or pointed cell. The figure and minute anatomical characters vary considerably, so that the above general description may require modification when applied to individual instances. Thus the hairs of certain plants are attached by their middle,

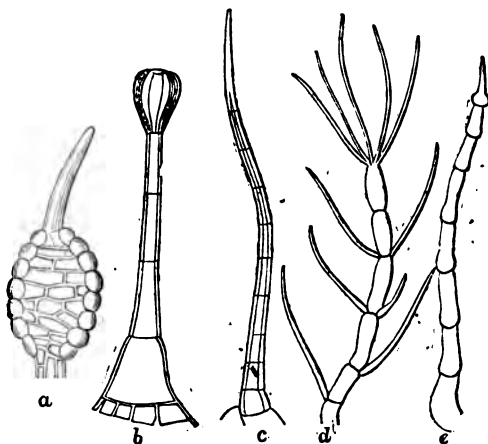


Fig. 112.—Variously formed Hairs. *a*, a gland, surmounted by a hair. *b*, a hair with an enlarged and secreting free extremity. *c*, *e*, simple hairs with pointed extremities. *d*, branched hair.

and have both ends free. Such are those of *Indigofera*, *Cap-sella*, and *Astragalus asper*; but in order to bring these within the definition above-mentioned, it is customary to assert that it is not one single hair attached by its middle, but two hairs springing from the opposite sides of an elevated cell. Such, doubtless, is the correct explanation of hairs which assume a stellate or star-like form, and which are really clusters of hairs attached each by one extremity. This variety is met with readily on the leaves of the Mallows, in which, with the assistance of a small hand magnifier, the stars may be perceived. The most beautiful illustration, however, is that of the hairs of the *Dentzia scabra* and *corymbosa* (Fig. 102), and the *Eleagnus*, which, as has already been demonstrated, are coated with a layer of silica or flint. They are very resplendent when viewed with the light thrown upon, and not through them—that is, as opaque objects, and may aptly be compared to the jewelled star of the Most Noble Order of the Garter.

Certain hairs are bent at the points of articulation of the cells, whilst others have their points only thus distorted. This latter variety is seen familiarly in the common teasel (*Dipsacus*), and has been used with much sagacity by cloth-workers, for the purpose of raising the nap of the cloth. The extremity is hooked, and by that means adheres to an object with great pertinacity, as any one may prove by placing the fruit of the teasel in his hair (Fig. 113).

Another and very interesting modification is that in which the hair consists of a single cell, but having an elastic spiral fibre coiled up within it. Such hairs are almost imperceptible, so long as they remain dry; but elongate and expand, sometimes with a crackling

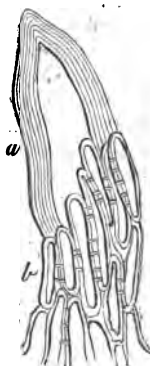


Fig. 113.—A prickly hair from the Fuller's Teazel (*Dipsacus fullonum*), consisting of a long, somewhat bent cell, thickened by layers, and embraced at the base by a mass of porous epidermis cells.

sound, on their immersion in water. They are found in the common mustard (*Sinapis*), which any one may examine after immersion for three hours, and have the form of an elongated cell, terminated by a bell-shaped expansion. In the seed-covering of the *Collomia grandiflora* and common sage (*Salvia*), each hair is simply an elongated cell of even diameter, terminated by a rounded obtuse end, and with a single coiled elastic fibre proceeding from the base to the apex. This is an interesting object, but requires considerable dexterity and quickness to see it with advantage. Slice the smallest portion of the outside of the common sage, and place it dry between two glasses under the microscope. No hairs will then be perceived; but if, whilst it is so placed, and the eye is upon it, a drop of water be insinuated between the glasses, until it touch the seed, there will instantly start out scores of long fibro-cellular hairs; and as the complete development occupies a perceptible interval of time, the eye may readily trace the process of elongation. When the change has been entirely effected, the object has no longer a defined smooth border, but is bounded all round by thread-like projecting points. A similar structure has been discovered in the hairs of the seed of *Acanthodium*, but with this difference, that two or three spiral fibres have been traced in one cell; and in some instances the fibres broken up into numerous rings. This is doubtless a beautiful object.

All the foregoing varieties of hairs may be termed single, but there are others which may fitly be designated as compound. Such are *toothed* hairs, in which there are short cellular projections on both sides of the hair; and *branched* hairs when the teeth are greatly elongated (Fig. 112 *d*). In a few instances this development is carried yet further, and the branches themselves are toothed, and the hair is said to be *plumose*. In others, the branches are restricted to one side of the hair, when the latter is termed *one-sided*.

But perhaps the most interesting circumstance in connexion with the anatomy of hairs, is, that in some plants, as the Sago-palm (*Cycas revoluta*—Fig. 114), the cuticle of the hair can be unrolled spirally. Professor Quekett has described this upon the fruit of that plant, and has delineated it in Fig. 114.

The foregoing remarks have exclusive reference to one great division of hairs—*viz.*, the Lymphatic, or such as bear innocuous fluids; but there is another large division which have a different conformation, and contain juices of highly acrid and poisonous properties. The sting of the nettle (*Urtica*) is a familiar and painful illustration, but the hairs of the leaves of certain tropical plants are yet better examples. These contain juices so poisonous, that if the hand grasp a leaf, it speedily inflames and swells, and so disturbs the whole system, that life is endangered. Such is the *Jatropha* when growing in our hot-houses even, and is handled only with the protection of a pair of thick leathern gloves. Moreover, if any part of the body be placed under this tree during a shower of rain, the poison which is washed from the plant by the water would, in like manner, cause very serious disease.

The anatomical difference between the lymphatic and secretive variety of hairs is, that

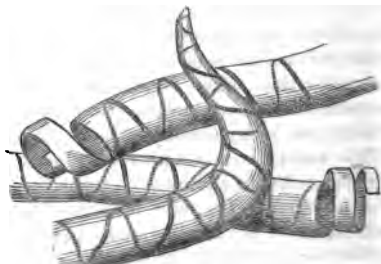


Fig. 114.—Portions of hair from the fruit of the Sago-palm (*Cycas revoluta*), exhibiting a spiral disposition of the membrane.

in the latter there is a bulging at the free end (Fig. 112, *b*), or immediately below the hard sharp-pointed apex (Fig. 112, *e*), which communicates with the other cells of the hair, or at the base of the hair, and contains a poisonous juice. Whenever such a hair is seized the sharp point enters the skin, and the end breaks off immediately below the point, and the contained fluid is emitted with a great impetus into the wound produced by the puncture. The juice in the perfect hair is maintained at a high state of tension, so that it may be emitted with violence, after the fashion of the poison in the poison-fangs of the serpent.

It will be inferred, from these remarks, that there must be a circulation of the sap in all kinds of hairs. Such is the case; and the circulation proceeds in currents from the base to the apex of the leaf and back again (Fig. 115, *B*). It may be seen proceeding under the microscope in the *Tradescantia virginica*, and appears to proceed between an internal and an external wall of tissue. At a certain period, a cytoblast (page 9) may be detected, and then the current appears to proceed from and return to it. When the hair has emitted its contents it shrivels, and in some instances (Fig. 116) retracts like the parts of a pocket-telescope.

Hairs are not found upon roots, nor upon any part of the plant which is buried in the ground or covered by water; and whenever they appear on one side of a leaf, it is, with few exceptions, on the under side. When a portion only of any surface is covered by them, it is uniformly the ribs or veins. They are sometimes found within the cells of water plants, as of the white and yellow water-lilies, *Nymphaea alba* and *Nuphar luteum*. Their functions appear to be that of promoting perspiration and of absorbing moisture, independently of that of secreting fluids.

Hairy surfaces have received various names, according to the nature of the hairs which cover them, as *rough*, *silky*, *arachnoid* (resembling a cobweb), *stellate*, *bearded*. The hairs themselves are also variously designated; thus, *stings* when they emit an acrid juice, and *glandular hairs* when the end is tipped with a fluid exudation (Fig. 112 *b*). *Hooks*, *barbs*, *bristles*, and *velvet* are terms which explain themselves. *Cilia* are long and sparse hairs, arranged in a row on the margin, as in the horse-leek, *Sempervivum tectorum*. *Hairiness* expresses a form of hair of a rather long and soft character, as seen in the common hemp nettle (*Galeopsis tetrahit*); *pilosity*, when the hairs are longer and more erect, as in the carrot (*Daucus carota*); and *villous*, when very long, straight, erect, and soft, as in the *Epilobium*. The term *tomentum* expresses a mass of hairs entangled and closely pressed to the skin, as in the *Geranium rotundifolium*. The longest hairs are probably those which envelop the cotton seed (*Gossypium*, Fig. 62, *B*), and constitute the cotton of commerce. They are also very long on seeds of the cotton tree,

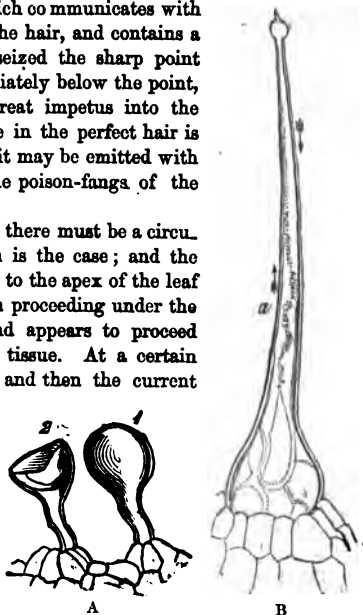


Fig. 115.—Stinging Hairs.

- A, 1, club-shaped hair, filled with the poisonous secretions of the Stinking Hellebore (*Helleborus foetidus*). 2, a similar hair, which has discharged its contents, and then collapsed.
B, pointed one-celled hair of the WIGANDIA URENS, filled with poison. The dotted lines show the current of the circulation, and the arrows its direction.

and in the willows of our own country. On ferns they are scattered, long, brown, and entangled.

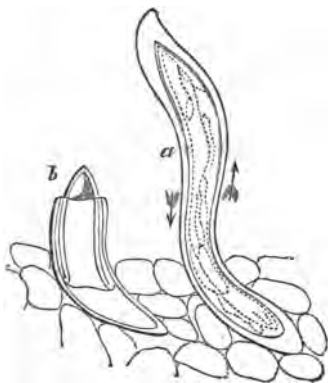


Fig. 116.

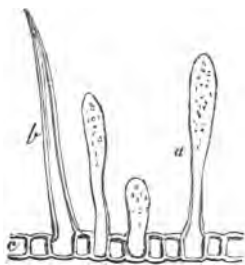


Fig. 117.

Fig. 116.—Two hairs from the style of a *CAMPANULA*, showing in *a* the circulation proceeding, and in *b* emptied of its contents. The latter is not only collapsed, but retracted within itself.

Fig. 117.—Representing the mode of growth of hairs from a single epidermal cell; *a*, club-shaped; *b*, pointed. Both from the Evening Primrose (*ENOTHEREAE*).

The development of hairs appears to be usually a very simple process, being none other than the inordinate growth of a cell of the cuticle on its free surface. Such is figured by Schleiden (Fig. 117).

Prickles are hard unyielding processes, with an acute and usually slightly curved extremity, well fitted to hold and tear any object which may be carried against them. They are very common in the rose (*Rosa*), and bramble (*Rubus*), in which plants they are the growth of a single year. In other plants, as the *Xanthoxylum juglandisfolium*, they are the result of two or three years' growth. They are essentially allied to hairs, since they are cellular prolongations of the cuticle, but differ greatly from them in their far greater development, the rudeness of their texture, and the functions which they perform. They have also a less real but a greater apparent resemblance to spines, as of the sloe tree (*Prunus spinosa*), inasmuch as both are large and rude, and sharply pointed; but there is this essential dissimilarity—*viz.*, that the spine is a prolongation of the wood of the tree (in other words, an abortive branch), whilst the latter is simply connected with the cuticle or the epiphloem of the bark of herbaceous shrubs. Their use is not well known; but they are not depositories or secretions, neither have they any independent circulation. They are well adapted to enable the long and slender branch to support itself by attachment to stronger plants, and also (if we may apply such an expression to a mere vegetable), to enable it to defend itself from the attacks of animals. They may be detached from the cutis by the force of the thumb and finger.

Scurf has been regarded as a production analogous to hairs, inasmuch as it is a cellular structure and is a process from the cutis. There, however, the analogy ends, and it fails in the most essential point—*viz.*, a similarity in function. It consists of scales of various forms and sizes, adhering to the cutis by the whole or only a part of

the surface; and when by a part only, it is the central portion; and the edges become irregular in outline and crenate. This latter peculiarity has induced a belief in the mind of an acute observer, Dr. Willshire, that the crenate scale in the *Adelia* and the *Elaeagnus* marks a transition from the simple scale to the beautiful stellate hairs of which we have just spoken, p. 65. Scurf is commonly met with in plants, and gives a spotted or leprous appearance to the cutis, as may be seen in the pine apple.

Ramenta are thin scales abundantly found on the backs of the leaves of ferns (*Alicies*), and on the young shoots of many plants. They are slightly foliaceous in their appearance, and not unlike the leaves of some mosses; but they want the structure, the position, and the leaf-buds of true leaves. Their function, as well as that of scurf, is unknown.

Glands.—We have now to consider a series of organs about which there has been much controversy—one party regarding them as remains of secretions and true secreting organs; and another (represented by M. Schleiden), doubting if such organs can be found in vegetables. M. Schleiden writes: "I have already remarked that I can connect no precise and definite idea with the term gland, as referred to a plant. No attentive observer can avoid seeing how different is life in different cells, whether they are found in different plants or in the same plant, or near each other. It appears to me quite foolish to denominate that cell or that group of cells which contains different matter from its neighbours a gland or organ for secretions; for there are many plants and parts of plants which would then consist only of glands. It is ridiculous to call a cell containing volatile oil a gland, and to refuse the name to one that contains red or yellow colouring matter; and should we call the last glands, then almost all petals would consist only of glands. The epidermis would be sometimes an epidermis, but sometimes a glandular surface, and with many single cells we should have to admit they are partially glands and partially not so."

The force of this reasoning will be perceived when we remember that all cells have contents, and that these contents have been secreted or produced within the same cell. Each cell is therefore both a secreting and a containing organ. Again, there is no anatomical structure in vegetables which is peculiar to these organs called glands, as distinct from mere ordinary cells of cellular tissue. In animals, on the contrary, there is in most instances a special glandular structure, and beyond this there is a series of cells called epithelium, to which is confided the duty of producing the larger part of the secretions of the body. These latter offer the nearest points of analogy to the glandular structures of vegetables.

But whilst admitting that there is a difficulty in defining a gland, there cannot be a doubt as to the existence of certain small hardened masses of cells, which perform the office of glands. Thus the nectarium, on the claw of the petal of the common *Ranunculus*, secretes a sweet honey-like substance, and is a true gland. So, also, with the glands situate beneath the cuticle, also the base of the pitchers of the *Nepenthes* and other pitcher plants. These pitchers contain a considerable quantity of water, not from having collected it from the air, but from the action of the glands referred to. In the latter instance there is a broad line of distinction between such bodies or glands and that of an ordinary secreting cell; for whilst in the latter case the secreted matter is retained within the cell, and the quantity corresponds with the size of the cell, in the former the secretion is altogether emitted from the gland, and its quantity is infinitely greater than the size of the organ which produced it. The subject is, however, involved in great obscurity, and it is probable that ere long it will be necessary to exclude such

cellular organs as the lenticular glands of the willow, and to include such reservoirs as the vittæ or receptacles of the volatile oils of plants.

Glands are sessile or sitting when resting immediately upon the cutis, as may be seen near the base of the ovary or seed-vessel of such pod-bearing plants as the *Crucifere*. They are also found upon the calyx of some campanulas, and upon the petiole or foot-stalk of the leaves of the peach, the cassias, and the passion flower. Their forms, colour, and appearance are very various, and of many it may be doubted if they are true glands.

Stalked glands (Fig. 118), are such as are elevated from the cuticle by something in the nature of a hair, and are *simple* if they consist of one or perhaps more cells and have a stalk of but one conduit and *compound* where there are several cells and several conduits. This division of glands has been termed indifferently stalked glands or glandular hairs. They are common in the rose and brambles, the *Hypericums*, the *Rue*, the *Tatropa*, the Snapdragon (*Antirrhinum*), the *Lysimachis*, the *Drosera* or sun-dew, and many other plants. In the sun-dew the hair of the leaf has an internal fibre, and is therefore a fibre cell; and the gland head consists of several layers of cells, the outer ones being small and cuticular, whilst the inner ones are long and columnar, and sometimes contain a spiral fibre.

Before proceeding to a consideration of the stems of wooded plants we will direct attention to two modifications which are met with, not exclusively, but chiefly, in herbaceous plants—*viz.*, first an enlargement of that part which is under ground, and which lies between the roots or rootlets below, and the true stem above; and secondly, such stems as take a horizontal rather than a perpendicular course above ground. These are termed respectively subterranean and aerial stems.

Subterranean stems, as the potato, onion, and turnip, include almost all the receptacles of starch, except seeds, provided for the use of man. There can be no doubt as to their analogies, seeing that they do not possess the anatomical and physiological properties of roots, and do, notwithstanding their deformity, resemble stems. They are commonly arranged under four heads—the bulb, corm, tuber, and creeping stem.

The *creeping stem (soboles)*, unlike the others is unimportant as an article of food, but yet is of great value from the property which it has of insinuating itself rapidly amongst the sandy particles of loose soils, and binding them together. It may thus lay the foundation of hills of sand which shall suffice to resist the encroachments of the sea. It is represented by the couch grass (*Triticum repens*), the bane of farmers, not only from the property above mentioned, but from the rapidity with which it multiplies itself whenever the stem is broken by the farmers' efforts to clear the land.

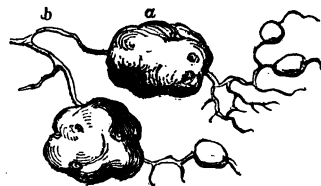


Fig. 118.—The underground stem of the potato (*Solanum tuberosum*), with its tuber, *a*, containing starch, and marked by growing points connected together by small bundles of fibre, *b*.

The tuber or potato is an irregularly ovoid enlargement of the stem, having upon its surface a number of growing points, familiarly termed eyes. The tubers of the same plant are all connected together and to the parent stem by

single bands of small diameter, consisting chiefly of woody fibre for the purposes of the

circulation of the plant. The precise mode in which the tuber enlarges is unknown; but it is quite clear that it must be freely supplied with circulating juices from the stem. This is effected by the woody fibre, and bundles of it ramify within the tuber, and pass to each growing point.

The structure of the tuber is very simple, being only a large mass of cells containing starch, inclosed in a layer of condensed cells or cuticle. The woody fibre and other structures bear no proportion whatever to the cellular tissue, and are not readily detached. The cellular character is at once evident by placing a very thin slice of it under the microscope, when a number of straight lines will be observed forming cells of much regularity, and inclosing a large number of starch cells (Fig. 83). The starch may be demonstrated by the addition of a watery solution of iodine whilst the section is under examination, when a beautiful violet colour will be instantly produced.

This form of stem is also found in arrow-root, and has a more regular figure in the asparagus potato.

The *Corm*, as in the crocus, colchicum, and arum (Fig. 119), is a rounded, flattened, solid organ, bearing a bud upon its point or at its side, and leaves from its upper part. It is a compressed stem, and is restricted to monocotyledonous plants, and intervenes between the true roots and the reproductive buds. It usually contains much starch, accompanied by an acrid poisonous secretion, which militates against its employment as an article of food.

The *bulb*, as of the onion and lily, is also an underground stem, or a stem in the rudimentary state of a leaf-bud. It is a fleshy, conical body, with scales surrounding



Fig. 119.—The *Cormus* of the *ARUM MACULATUM*, containing starch.



Fig. 120.—A tunicated bulb, with stem and roots.

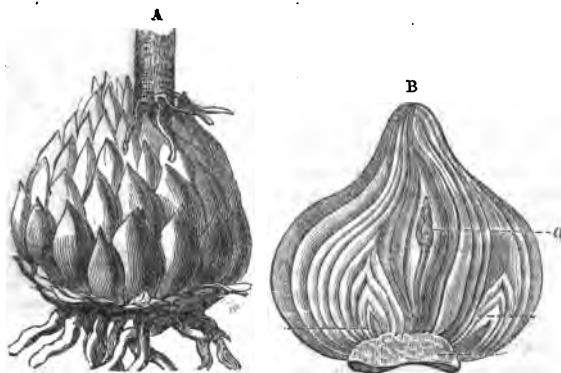


Fig. 121.

A, naked bulb of *LILY*, showing its lateral stem and foliaceous covering.
B, section of a bulb, showing its growing point at *a*.

a growing point, and emitting roots from its base, and thus theoretically resembles the leaf-bud of an aerial stem. It reproduces itself by developing buds, or cloves, at the



Fig. 122.—The **RUNNER**, emitting roots and leaves at intervals.

base of its leaves or scales, which buds grow at the expense of the parent plant, and at length destroy it. There are two kinds, according to the arrangement of the leaves : First, the *tunicated* (Fig. 120), when they more or less surround the whole organ, and cohere in a membranous sheet of tissue. Such is the case in the onion (*allium*). Secondly, the *naked*, when the scales are smaller and more fleshy, and are imbricated in rows, one above another, as in the tulip. Both of these forms contain much starch (Fig. 121), and also many raphides (Fig. 87). They are not so exclusively composed of cellular tissue as was noticed in the structure of the tuber; but also contain vascular and woody structures.

Aërial Stems are of five kinds, the Sucker, the Vine, the Root-stock, the Runner, the Offset, and the Pseudo-bulbs of orchidaceous plants.

The Sucker is common in monocotyledonous plants, as the pine-apple, and consists of a branch proceeding from the column of a plant underground, which becomes erect and bears leaves, and subsequently emits roots from its base. In other instances it proceeds from the stem downwards to the earth, and there takes root.

The Vine, as in the Vine (*Vitis vinifera*) and Cucumber (*Cucumis*), is a slender twining stem, which situates itself amongst and adheres to other plants for support. It does not give off roots along its course.

The Runner, on the other hand, is also a creeping stem; but it emits a bundle of



Fig. 123.—The **GINGER** plant (*Zingiber officinale*), with its rhizome, from which the leaves and flowers spring.

roots and leaves at intervals, and, in fact, forms new plants (Fig. 122). Such is the Strawberry (*Fragaria*).

The *Offset*, as in the House-leek (*Sempervivum tectorum*), is a short branch terminated by a cluster of leaves, and capable of independent existence after separation from the parent plant.

The *Rootstock*, or rhizome, is a thickened rooting stem, as in the Ginger (Fig. 123), and Iris, which produce young branches or plants yearly.

The *Pseudo-bulbs* of orchadaceous plants (Fig. 124) very closely resemble tubers, except that they retain the marks of leaves which they once bore. They exist above ground, and contain amorphous starch.



Fig. 124.—The tubers, or pseudo-bulbs, of the Spider orchid.

Wooded Stems.—Having now offered such remarks on herbaceous stems (distinguished from woody stems) as seemed to be required by their greater delicacy, we proceed to describe woody stems and their appendages. When treating of the modifications of herbaceous stems (page 59), we intimated that such changes also affected woody stems, but in a lesser degree, and shall therefore not again refer to them under this head.

There are, however, a few preliminary remarks which are necessary as to the general conformation of the tree before we enter upon an examination of the internal structure.

The general divisions of a stem are called *branches* (*rami*), and the arrangement of them as a whole is termed *corona*, a head, as that of a forest tree. (Figs. 125, 126.) When they proceed from either side of the stem, and then pass from the base to the apex of the tree, it is called a *caulis excurrentis*; but when the stems break



Fig. 125.—The BEECH TREE (*Fagus*), showing the *corona*, or head, of forest trees.

up into a mass of branches, it is known as a *caulis deliquescentis*. Incompletely grown shoots are termed *innovations*, and *ramuli*, or twigs, when very young. If the shoot is long and flexible, it is called a *vimen*; and when it proceeds from the stem at nearly a

right angle, it is called *brachiate*. This arrangement of the branches is further used to distinguish trees, shrubs, and herbs. A tree (*arbor*) is composed of a trunk supporting perennial branches; and, when small, it is called *arbusculus*. A shrub differs from a tree in there being no central stem or trunk, but the branches proceed directly from the earth. This is called *frutex fruticulus* when small, and *dumosus* when low. The undershrub (*subfrutex*) has the same arrangement of branches; but it approaches nearer to the herb, since it wholly or partially dies annually. It has, however, wooded branches, and not merely or chiefly cellular ones. The stem of a forest tree, and of any other which has not its growth terminated by a flower-bud, or any other organic cause, is said to be *indeterminate*, and *determinate* when otherwise.

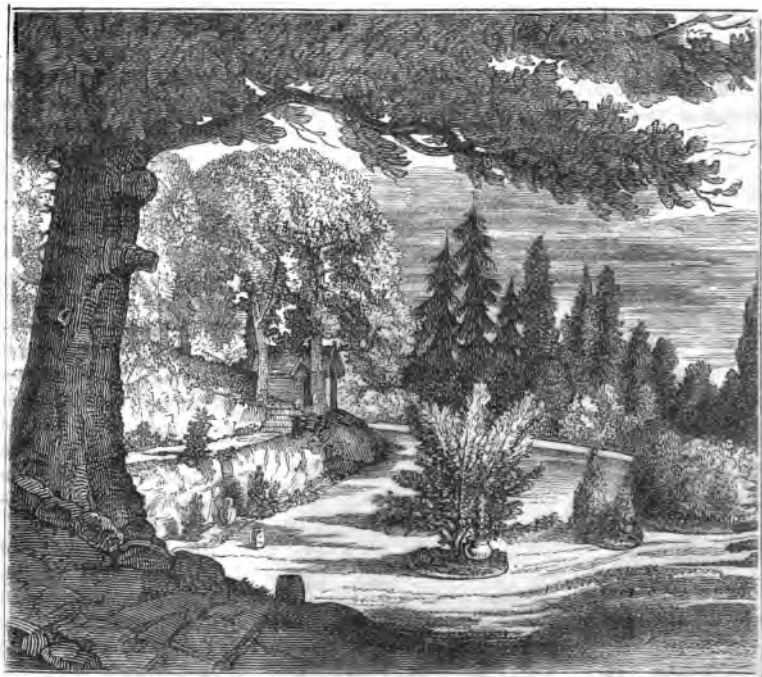


Fig. 126.—Representing a variety of trees, all of exogenous growth.

The science of Botany is rich in descriptive terms; and although they may be disagreeable to a student, are very welcome to the botanist who would intelligibly describe a plant. We must therefore counsel our readers not to pass them hastily by, but to read them attentively, and, if possible, commit them to memory.

Wooded Stems are divided into two great and well-defined classes, according to their internal conformation—*viz.*, such as grow from without (*exogenous*), and such as enlarge from within (*endogenous*). The former are more common in cold, and the latter in hot climates. There are, however, the following points of resemblance:—Each has a

cellular basis through which the bundles of wood pass, and each is inclosed by a cuticle or bark (endogens are said to have no bark). The cellular system is horizontal, and constitutes the woof of the structure; whilst the vascular and woody system is longitudinal, and corresponds to the warp.

Exogenous Stems.—On examining a section of the stem of an oak, or any other of our forest trees (Fig. 127), we observe the following parts—first, the pith, *a*, or its remains, in the centre; secondly, the bark, *d*, on the outside; thirdly, a mass of wood, *b*, between the two, broken up into portions by the concentric deposition of its layers, and by a series of lines or rays, *c*, which pass from the centre to the circumference. Thus there are always pith, bark, wood, and medullary rays (Fig. 127). It has already been mentioned that each stem has two systems, the cellular and the vascular; and the parts just mentioned must belong to one or other of those systems. Thus the pith, medullary rays, and bark belong to the horizontal or cellular system; and the wood, with its associated ducts, constitutes the longitudinal or vascular system.

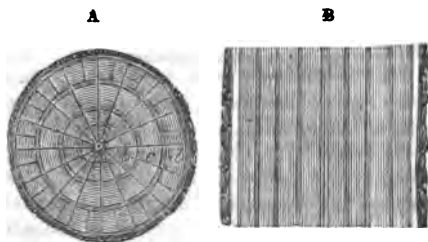


Fig. 127.

A, transverse, and B perpendicular section of an exogenous stem, showing parts of which it is composed. *a*, the central pith; *b*, four layers of woody fibre; *c*, the cambium in the spring; *d*, the bark; *e*, the medullary rays.

This division of stems comprehends nearly every wooded plant of our climate.

The *Pith* occupies the centre of the stem (Fig. 128, *a*), and remains throughout the period of growth of some trees, as of the elder (*Sambucus nigra*), or is absorbed after a few years, as in the oak and almost all large trees. In the latter class of plants there are some remains of the pith for many years after the process of absorption has commenced; but at length no vestige can be detected, and its position is known only by the central spot around which the wood is placed in circles. It is, however, at this period found in young shoots just as it was at the earliest moment of the formation of the plant (Fig. 129).

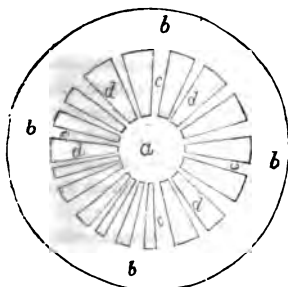
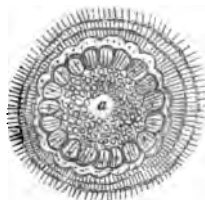


Fig. 128.—A scheme of the parts of an exogenous stem.

a, the pith; *b*, the bark; *c*, medullary rays uniting the pith and the bark (greatly exaggerated); *d*, woody fibre.

branch and leaf-bud; but is sometimes thickened, and rendered more dense, as in the ash, at the nodes—the place, indeed, where all the structures are somewhat compressed.

Its structure is at all times cellular; and, for the most part, the cells are hexagonal in form, as shown in Fig. 11.

Fig. 129.—Section of young shoot of the MAPLE TREE (*Acer campestre*), showing the large size of the pith, *a*; the bundles of wood of one year's growth, and the bark with its hairs.

The cells are commonly

of large size, and may be well examined in the pith of the elder. Their colour is green whilst they freely perform their function; but subsequently the tissue is nearly colourless. In the old age of the plant the pith often assumes a colour which it has

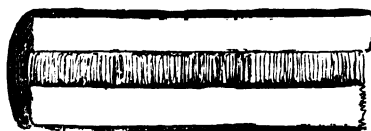


Fig. 130.—Chambered pith in the WALNUT.

obtained from the juices which have been deposited within it. In a majority of instances the pith forms a solid cylindrical mass; but in certain fast-growing plants, as in the hollow stems of the *Umbelliferae*, it is torn, and vacuities are left. In a few plants the ruptured pith assumes a very regular form, and is thence termed chambered pith, since it is divided into a series of compartments which pass across the column in small stems. Such is the case in the walnut (Fig. 130), as may be readily seen by selecting a very young shoot and slicing away a portion of one or both sides. According to the researches of Professor Morrison this change depends upon the lateral elongation of the cells, and the consequent disappearance of the contents of the cells, and is induced immediately by the absorbing action of the leaf-bud.

The connexions of the pith are highly important, and demand special enumeration. It has already been intimated that it does not exist in the root, at least, of tolerably grown plants, and therefore its functions are confined to the stem. First. It is in direct and unbroken connexion with every branch, leaf, bud, and flower, and is the structure which first conveys fluids to, and receives fluids from, the newly-developed leaf. It thence becomes the main organ of nutriment; and, at the same time, the chief depository of the secretions. Secondly. It is in equally direct and unbroken connexion with the bark, through the medium of the medullary rays; and thus becomes the centre of all the movements of sap which proceed in the horizontal system;—it is that system which more especially presides over the life of the plant.

The mode in which its ultimate disappearance occurs has been a matter of doubt and speculation. It seems quite clear that it is not converted into wood, as was asserted by Mirbel, and there are certain facts which militate against the opinion that it is gradually compressed by the wood; but since it is known that in the growth of the plant much compression of the previously formed wood must occur, and since this compression is a reasonable theory by which to account for the disappearance of the less resisting pith, it is now pretty generally admitted to be at least one of the causes of this occurrence.

As a general rule, the pith, so long as it exists, is not mingled with other than cellular structures; but, in a few instances, woody fibre has been found with it; and in others, as *Nepenthes*, spiral vessels have been detected.

The economic uses of pith have not been numerous, but amongst them must be mentioned the rice-paper used in China, and prepared by Kieung; the pith of the *Æschynomene* (Fig. 48), and the *Aralia papyrifera*, in a circular manner, so as to obtain large, thin, and evenly cut sheets. It is used for drawing and for writing. The cellular pith-like stems of the *Æschynomene aspera*, called "shola," have been forwarded to this country from India, and have been made into various ornaments, models of buildings, hats, boxes, and life-buoys. Its lightness, and non-conducting property of heat, render it very fitted for the manufacture of hats.

Medullary Sheath.—Immediately surrounding the pith of all exogenous plants there is a layer of vascular tissue, which has received the name of medullary sheath

(Fig. 128). This sheath has no special walls, but is simply bounded by the pith on the inner, and by the wood (when it exists) on the outer side. It is in this situation that we may find ducts of various kinds, and spiral vessels; and in all cases it conveys the vascular structure from the root direct to each leaf and flower. The integrity of this structure is therefore highly necessary to the life of the plant. It is said to retain its green colour to the latest period of the existence of the plant; thus showing the importance of the functions assigned to it.

Medullary Rays.—These structures come next in order; and, as has been already intimated, belong to the horizontal cellular system of the stem. They constitute the channels of communication between the bark and pith, and are composed of a series of



Fig. 131. Vertical section of an exogenous stem across the medullary rays, showing their open character and their relative position to the wood.

a. Dotted duct.

b. Woody fibre.

c. End of medullary rays.

walls, of single muriform cells resting upon the root, and proceeding to the apex of the tree, and radiating from the centre. They lie between the wedge-like blocks of wood, and, as they have a lighter colour than the wood, they are evident on a section of any stem, and are called the silver grain (Fig. 131). Their colour and number suffice to enable us to distinguish various kinds of wood, and greatly increases their beauty. They cannot, of course, exist before the wood is formed, and are therefore not met with in the earliest condition of the plant. They begin to exist with the first deposited layer of wood, and continue to grow outwardly, or nearest to the bark, so long as the wood continues to be deposited.

The Bark.—As the medullary rays terminate in the bark on their outer side, we are naturally next led to a consideration of that structure. It forms the outer covering—a sheath of the tree, and, in some form or other is present in all plants. When discussing the constitution of the cuticle of herbaceous plants we explained the points of difference between the two varieties of the same structure, and showed that the rudeness of the bark of wooded trees had destroyed many of the characters of the cutis, such as stomata and hairs. We have now to regard it as a dense cellular organ, well fitted to endure the influences of seasons through a long series of years.

It may anatomically be divided into two structures—viz., an outer one, which is cellular, and an inner one, which is vascular or woody. The former is sub-divisible into three parts, whilst the latter is composed of several layers of the same material, and forms a link between the wood and the bark.

The three divisions of the cellular part are the Epidermis, the Epiphleum, and the Mesophleum.

The *Epidermis* is the most external layer, and is continuous with that upon the leaves. Its cells are flattened and lengthened, and but very rarely possess stomata.

The *Epiphleum* has acquired much importance from the fact of its being the part of the bark in which the cork is deposited. It cracks and peels off at intervals in almost all trees. In the birch and cherry it may at all times be seen hanging from the stem in silvery shreds, and in other trees as rough broken patches. In the cork tree (*Quercus suber*) it remains firm until the tree has attained a certain age, after which it exfoliates in the large masses in which it is brought to this country. It is probable that the deposition of cork proceeds in all; trees but in the cork tree it attains so great a thickness as to become a highly important article of commerce.

The removal of the cork from the tree is not left to natural exfoliation; but, when

the tree is sufficiently mature, incisions are made from the top to the bottom of the stem, so that the cork may be more quickly removed. The sheets are then placed upon the ground to flatten, and are at length cut up into convenient lengths for packing. The tree will permit this process to be renewed during seven or eight successive years.

The cause of the exfoliation has not well been determined. It certainly does not depend upon the growth of the tree, as though the increased size of the stem caused the bark to rupture and thence to fall off; but it is said that a layer of tabular cells are formed within it which cuts off its communication with the internal structure of the stem, and thence it dies. No doubt can exist as to the fact of the constant destruction of the old bark and the formation of new structures, and it appears to arise either from the death of the external layers only, or from the formation of cork on the innermost layer of the bark, which causes an arrest of the circulation, and at length the death of the more external parts.

It is said that the bark of exogens is much more extensible than that of endogens; and that, as a consequence, the stems of the former exceed in diameter those of the latter. But the fact just mentioned seems to prove that in fact the cellular part of the bark of exogens possesses but little extensibility; for, when the enlargement of the trunk has proceeded but even to a moderate extent, the bark cracks off from a lack of this power of extension. It is far more probable that the increasing size of the zone of bark is less due to the extensibility of the old bark than to the formation of new cells year by year as the stem enlarges, and in a layer at all times proportioned to the increasing size of the stem—in fact, that the old coat becomes too small, and rends, and a new one is supplied of larger dimensions. It is quite clear that the external layers, after rupture, either peel off, or the width of the rents increases as the tree grows larger.

The *Epiphleum* consists of several layers of thin flattened cells, usually without colour.

Thirdly, the *Mesophleum* is a thin layer of green cells lining the epiphleum, and, in the cork tree, exfoliating with it. Its cells lie in a direction different from that of the cells of the epiphleum, and sometimes contain cellular secretions.

The vascular part of the bark is called the *liber*, from its offering a smooth enduring structure, which was formerly used as paper (*liber* a book). It consists of several



Fig. 132.—Bark of the Lace Tree of Jamaica, composed of fine and loosely arranged bundles of woody fibre.

layers of small interlaced bundles of woody fibre, connected together by loose cellular tissue. In some trees, as the lace bark tree (*Lagetta linearia*, Fig. 132), it resembles a textile fabric, and may be obtained from the tree in sheets of large size. The woody fibre of the liber has always the peculiarity of being very strong, and of lying in small bundles, and has been used as cordage by most nations. It is still employed in Russia in the manufacture of mats, and in many parts of the world for whiplashes. It is not equally smooth on both aspects; since, on its outer side, it has cellular connexion with the mesophleum, but on its inner surface it is opposed to the smooth wood, or is covered by the semi-fluid cambium. Its mesh-work character permits the medullary rays to pass through it, and to keep up a circulation with the cellular part of the bark. It is not subsequently converted into the wood of the tree,

as some have supposed, but is formed in the Spring season from the leaves with the wood, and lies in successive layers within the mesophlæum.

The more immediate use of the bark is that of giving protection to the wood. If bark did not exist there would be no cambium, and without cambium there could not be any deposition of woody fibre; and thus the presence of bark is necessary to the growth of the tree. It is also essential to the life of the tree, from its connexion with the cellular system, and with the undeveloped leaf-buds.

The bark contains a large number of air vessels and *vasa propria*, and not only conveys refuse matter from the leaves to the soil, but is in almost all cases a depository of elaborated secretions. This is well seen in the oak bark, yielding tannin; the cinchona bark, producing quinine; and the fir-tree, emitting turpentine. There are also many milk vessels; but, with the exception of the *Nepenthes*, there are no spiral vessels. We have oftentimes found thick wall-cells, as in Fig. 40, arranged in columns with great regularity.

Wood.—We now proceed to the most important division of the parts formed in exogenous stems—*viz.*, the Wood—a substance not merely giving stability and beauty to the tree, but offering the greatest service to man. We find it occupying nearly the whole body of the trunk, and arranged, as a rule, in a very regular manner in this class of trees. On taking up any piece of wood, but more particularly the entire section of a stem, we first notice a series of circles, which increase in diameter, and separate by wider intervals as we approach the bark. In this manner the trunk is composed of numerous zones inclosed within each other. Again, in almost all trees, we observe the medullary rays before-mentioned passing in straight lines from the centre to the circumference; and as the circle of the stem at the bark is much larger than any circle near to the centre, it follows that the medullary rays will be wider apart at the bark than at the pith. On this view of the subject we may state that the stem is composed of a series of wedge-shaped blocks, which have their edges meeting at the centre. The combination of these two views gives the correct idea of the arrangement of the wood—*viz.*, a series of wedges, each divided into segments of unequal width by circular lines passing across them. From this description it must not be supposed that these various portions are detached, or may be readily detached, from each other; for, although the medullary rays and the circular mode of deposition both tend to a less difficult cleavage of the wood, they yet bind the parts very closely and firmly to each other.

The explanation of the occurrence of distinct zones of wood is that each zone is the produce of one year, and that in our climate, more so than in tropical countries, the period of growth of wood ceases for many months between the seasons, and thus induces a distinction in appearance between the last wood of a former and the first wood of the succeeding year. This distinction is maintained throughout each year, and throughout a long series of years.

The inclosure of zone within zone is owing to the mode in which the wood is produced, and the position in which it is deposited. Wood is formed by the leaves during the growing season, and passes down towards the root between the bark and the wood of the previous year (if any), or in the position in which cambium is effused; and, as the

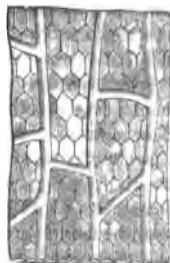


Fig. 133.—The branching vessels of the bark along which the fluids are conveyed.

leaves more or less surround the whole stem, the new layer at length completes a zone, and perfectly encloses the wood of all former years. This is the explanation of the term *exogenous*, which is derived from two words signifying to grow outwardly, for the stem increases in thickness by successive layers on the outer side of the previously-formed wood. That this is the mode of growth has been abundantly proved by experiment, and demonstrated by accidental discoveries. Thus, if a plate of metal be inserted between the bark and wood, it will in progress of time become inclosed by the new wood which has overlaid them. So in like manner, if letters be cut deeply through the bark and into the wood, the spaces will not be filled up from the bottom, but may be seen in subsequent years overlaid by new wood. A statement appeared in a daily paper, during the past year, to the effect that in cutting down a tree a cat had been discovered inclosed in the wood of the trunk. These facts prove that the wood is applied from without. Again, if a branch be stripped of its leaves down to a certain point, it will not grow above that point; and so, in like manner, if branches be stripped from one side of a tree, the tree will not grow on that side. If a circle of bark be removed from a branch above and also below a leaf, it will be found that increase of size will occur below, but not above that bud; and so, likewise, whenever a ring of bark is removed from a tree, the new woody fibre will not proceed from the lower but from the upper edge. Further, if a scion be engrafted upon a stock having wood of a different colour from that of the scion, it will be found that the wood produced from the scion overlays that of the stock. This may actually be seen in operation in the spring season, if a leaf be exposed immediately below its base; for then bundles will be seen to shoot below the ring of bark or cuticle, and to divide into two sets, one of which proceeds to the *liber*, and the other to the wood of the trunk.

These facts are undoubted, and the inferences seem to be indisputable; but yet various men of eminence have held contrary opinions. Thus, Linnæus believed it to be the produce of the pith, and Malpighi, that of the last year's wood; whilst Du Hamel affirmed that it was produced by neither, but solely from the cambium, which, according to him, was secreted by the bark. It cannot be denied that the bark exercises an influence in the formation of wood; for if a zone of red bark be made to grow upon a tree having white bark, all the wood appearing below this new bark will be red. But this is not the result of any power in the bark to form wood, but simply that the wood, as a part of the horizontal cellular system of a plant, has a controlling influence over its secretions. These experiments, and others of a similar character, may be most readily performed by any one of ordinary ingenuity. And what amusement could be more instructive to our young friends of both sexes, and possibly through them to the world at large?

If our readers will cursorily glance at the cut surface of any stem, they will at once perceive another fact in relation to the zones of wood, *viz.*, that whatever may be the thickness of the zone for the year, it is rarely equal around the whole circumference of the stem. This is no matter for wonder; but, on the contrary, it is surprising that there is any approach to regularity, seeing that the position of leaves upon the branches seems to be an accidental rather than a circular or spiral one. The occurrence is readily accounted for on the theory above propounded, and is due to the lesser abundance of leaves on the branches of one side than on the other, or to the prevalence of winds, or some other physical cause, acting in that direction in opposition to the growing process.

Figs. 134, 135, 136, 137, 138 exhibit horizontal and perpendicular sections of an exogenous stem, from the end of the first to the end of the fifth year. In each figure



Fig. 134.—End of first year's growth.

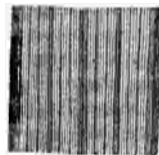


Fig. 135.—End of second year's growth.

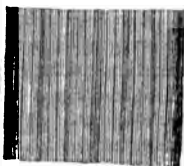


Fig. 136.—End of third year's growth.

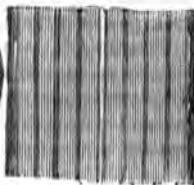


Fig. 137.—End of fourth year's growth.

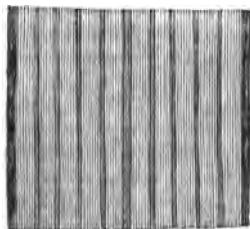


Fig. 138.—End of fifth year's growth.

the pith occupies the centre, and is the largest at the end of the second year; after which it progressively diminishes. Immediately around it is the medullary sheath. The bark is on the outer boundary; and the woody and pitted tissues occupy the intervening spaces, and increase at the rate of

one layer or zone per year. The medullary rays pass from the pith to the bark.

From the preceding remarks it will at once be inferred that a plant of one year's growth has but one layer of wood; and that that, therefore, does not inclose wood, but pith only. When the tree has reached the end of the second season it will have two layers; and so on, successively, through any number of years. The above Figures represent each a horizontal and vertical section of a stem at various periods; and in Fig. 138 it will be seen that the stem of a plant five years old exhibits a central pith, five zones of wood, and the bark, besides the cambium in the spring season and the medullary rays.

The age of trees has been inferred, when a section of the whole stem could be examined, by counting the number of rings of wood which have been deposited around the pith. When only a part of the stem remained, and yet its original diameter was known, the same end has been sought by multiplying the width of one zone by one half the diameter, or by counting the number of zones from the pith to the bark, should so

much of the stem be found. In a large proportion of cases these modes will evoke tolerably accurate results; but there are several sources of fallacy to which we must refer.

First, it is highly probable that in tropical climates the wood of more than one year may produce but one zone; for as there is but a short if any period of cessation of growth, but very slight evidences of any line of demarcation can be detected. The real age of trees may thus be underrated.

Secondly. It is highly probable that in some plants more than one zone of wood is formed in the year; for such is evidently the case in the root of the *Beta Vulgaris*. This would unduly increase the age of the tree.

Thirdly. When examining a fragment of a tree the observer should remember that the zones are not of equal thickness throughout, and that it is quite possible that in some years no wood whatever was formed in the fragment under examination. The varying width of zones results from the age of the tree; so that it is less as the tree advances in life, as also from the interruption to growth, which not unfrequently continues on one side of a plant throughout a greater part of the growing season. This may be readily observed by noticing a section of almost any stem; for then it will be evident that the pith does not occupy the geometric centre of the plant. Dr. Lindley gives the measurements of two sides of four stems, which he selected from East Indian trees, which exemplify this fact clearly:—

	Real age or No. of zones.	Total diameter.	Diameter of	
			Smaller side.	Larger side.
1st stem . .	40	45 lines.	9 lines.	36 lines.
2d „ . . .	36	30 „	8 „	22 „
3d „ . . .	17	31 „	11 „	20 „
4th „ . . .	8	34 „	11 „	23 „

“Suppose that a portion of the smaller side in the first example were examined, the observer would find that each zone is 0·225 of a line deep, and as the whole diameter of the stem is 45 lines, he would estimate the side he examined to be 22·5 lines deep, consequently he would arrive by calculation at the conclusion that as his plant was one year growing 0·225 of a line, it would be a hundred years in growing 22·5 lines, while in fact it has been only forty years.”

Thus, whilst it is difficult to ascertain with great certainty the age of any tree when a whole section can be obtained, the difficulty is vastly greater when only a fragment can be examined.

The great size of the trunk of a tree is *prima facie* evidence of its antiquity; and judging from that fact alone we should be disposed to admit that the following remarkable trees must be very aged:—

The Chestnut of Mount Etna (*Castanea de Centa Cavalli*) is 180 feet in circumference.

A Plane tree in Turkey, 150 feet in circumference.

Some of the Brazilian *Hymenæas*, 84 feet in circumference.

In respect of height, it is known that the *Araucarias* sometimes attain to the height of more than 200 feet.

The *Pinus Darglariana* of Oregon is 193 feet high; and the *Pinus Lambertiana* is 226 feet in height.

The real value of these enormous dimensions will be best felt if our readers would make a circle in a field of 180 feet in circumference, and then measure a distance of 70 yards to indicate the width and height of a tree.

There are several ancient oaks in England, through the remains of whose hollow trunks coaches have been driven; and in New Zealand it is said to be a common occurrence to use decayed trees as stables.

The following list of ancient trees may be found in a French work, the "Tératologie Végétale," and their ages have been computed upon the principles now laid down:

List of old trees, according to Magnire and Tandon. There are known:—

Palms of	200, 300 years.
Cereus	300 "
Chirodendron	327 "
Ulmus (Elm)	355 "
Cupressus (Cypress)	388 "
Hedera (Ivy)	448 "
Acer (Maple)	516 "
Larix (Larch)	263, 576 "
Castanea (Chesnut)	360, 626 "
Citrus (Orange)	400, 509, 640 "
Plantanus (Plane)	720 "
Cedrus (Cedar)	200, 800 "
Juglans (Walnut)	900 "
Tilia (Lime)	364, 530, 800, 825, 1076 "
Abies (Spruce)	1200 "
Quercus (Oak)	600, 800, 860, 1000, 1600 "
Olea (Olive)	700, 1000, 2000 "
Taxus (Yew)	1214, 1466, 2588, 2888 "
Schubertia	3000, 4000 "
Leguminosæ	2052, 4104 "
Adansonia (Baobab) of Senegal	6000 "
Dracæna (Dragon's Blood Tree) of Teneriffe	6000 "

When we remember that the two latter periods carry us back to the days of Adam, and contrast them with the ordinary destructibility of vegetable growths, they appear to be incredible, and we cannot but suspect that some elementary error has crept into the computation.

Since the quantity of woody fibre produced depends mainly upon the number of leaves upon the tree, and the number of leaves must bear some proportion to the size of the tree, it might be inferred that the quantity of wood deposited would increase with much regularity as the age of the tree advanced. This increase might be manifested in two, or one of two ways—*viz.*, the increasing length of the zone and its increasing width. It is very probable that an increase does take place in the annual deposit, until the tree has attained its maximum of growth; and it is quite clear that so long as the tree enlarges, the circumference of each zone must increase likewise; but there is no evidence that the zone at the same time increases in thickness. This militates against the oft-repeated attempt to determine the age of a tree from its diameter; and if there were no other source of fallacy, it would suffice to remind our readers that the growth of trees must depend upon the varying nature of the soil, the

changing seasons, and the prevalence of winds; and that all these act with tenfold greater effect upon a full grown than upon a very immature tree. It may therefore be affirmed, that the zones of wood increase in length, and decrease in thickness, as the age of the tree advances, and that both proceed from determinate causes, but that the increase and decrease alike do not follow any rule of universal application.

Moreover the width of the zones of wood, in the same species of tree growing in different positions, is not the same. Thus the Scotch Fir (*Pinus sylvestris*), growing at various altitudes, produces rings of wood varying from 0.39 lines, to 10 times that amount. That such must be the case we may readily infer from the fact, that in any plantation trees of the same species, and planted at the same time, attain, within a few years, to very different dimensions. This dissimilarity is far greater when we compare trees of various species; but yet, in reference to all wooded plants, it may be stated that there is a general resemblance in the size, both in height and thickness, which plants of the same species attain in the course of years.

Numerous efforts have been made to discover a relation between the height and the thickness of trees; but whilst there may be an approach to similarity in trees of the same species, there is not a shadow of resemblance in wooded plants as a whole. Thus it has been found, that of two species of Pine the difference was so great, that whilst the relation was as 1 to 5 in one instance, it was as 1 to 120 in another.

Such speculations may tend to increase a spirit of inquiry, but hitherto they have had no other good effect.

The foregoing description may suffice for exogenous stems which follow this usual course of development, and therefore for the great majority of trees; but it is readily conceivable that a difference in figure may exist to a great extent, as in the cells of cellular structure, considered at page 11.

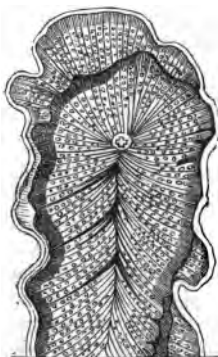


Fig. 139.



Fig. 140*.

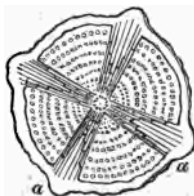


Fig. 140.

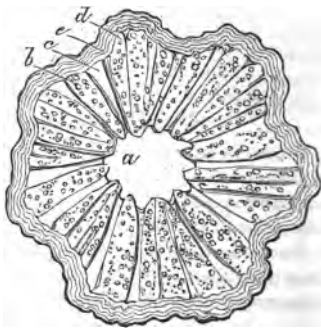


Fig. 141.

Fig. 139, representing the section of a tree in which, from the irregular development of the stem, there are no concentric zones of wood.

Figs. 140 and 140*, showing, in the section of a stem of a Bignonia, four internal deposits of bark, *a*, by which the wood is divided into four wedges. The lines crossing the centre are well developed medullary rays.

Fig. 141.—The stem of a Clematis, in which the medullary rays are greatly thickened. *a*, the pith; *b*, the smaller; and *d*, the larger wood bundles; *c*, the large medullary rays; *e*, the bark.

Thus, whenever the process of growth is so disturbed that it proceeds on one side, whilst it is nearly arrested on the other, it is evident that the figure of the stem will

not be cylindrical, and that the layers of wood will not be in perfect zones. So also when this disturbance is restricted to a portion only of one side, there will be no growth at that part, and in process of time a depression in the stem will result, giving it a furrowed appearance. At a still later period, assuming that the like causes exist, this furrow will become deeper, but at the same time it will be narrower; for the woody fibre, as it passes down on either side, will find little resistance in that direction, and will push into the furrow and lessen its size. At the same time the bark will also increase in thickness, and in process of time the original furrow will have disappeared. A section of such a stem would show a triangular interval in the circumference of the trunk, which would either be vacant or filled up with layers of bark. If, whilst these changes are proceeding, others of a similar character were met with in other parts of the circumference, the section, instead of exhibiting a circular outline, would greatly resemble the figure of the stellate cell (page 11). These are the explanations of a great variety of twining stems growing in hot climates, and which are angular, or present a cruciate appearance on section.

An interesting modification, and one very nearly allied to the above, is that in which the medullary rays increase in thickness so greatly as not only to be mere lines, giving a grain to the wood, but large wedge-shaped blocks between alternate masses of wood. This is not remarkable, when we remember that at every moment of growth there are two processes going on, one the cellular or horizontal, and the other the woody or vertical; and it is no more a matter of surprise that nature should occasionally increase the one at the expense of the other, than that she should rigidly adhere to the rule which she has laid down; for both the rule and the exception are alike wonderful and inexplicable. Such exceptions, greatly varied, but yet for the most part originating in the "Wood," or cellular structure of the stem, are by no means uncommon.

The general configuration of exogenous stems is conical, the circumference being, for the most part, circular, and the base much larger than the apex, or the free terminal part of the stem. This necessarily results from the remarks which we have made on the production of wood; for it is manifest, that if the wood be a product of the leaves, and the number of leaves on the tree increases from above downwards, the quantity of wood deposited will be greater below than above. The apparent exceptions to this rule are in such fast-growing trees as grow in the midst of a dense wood, where the light reaches them only at the top. Such trees run up of nearly even diameter, and without a branch, until more than two-thirds of their entire height has been attained; but from the point where branches arise, the conical figure may readily be traced. The common asparagus

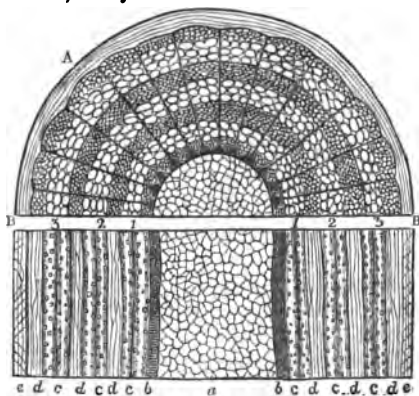


Fig. 142, showing the component parts of a stem in the fourth year of growth.

A, a part of a transverse section. B, a perpendicular section, the parts of each arranged accurately over the other.

a, the pith; b, the surrounding medullary sheath; c and d layers of wood and bothrenchym intermingled. The open-work in A shows the position and the extent of bothrenchym more clearly; e, the bark.

plant is also said to be an exception to this rule. The circular figure of the stem is due to the somewhat even distribution of the leaves around the trunk; and this will be the most perfect when the tree has grown apart from others, and where it is freely exposed on all sides to the influence of light.

The wood of plants is not composed exclusively of woody tissue, but with that structure is bothrenchym, or dotted tissue and ducts, in greater or less abundance. This, as before mentioned at page 17, is more particularly the case in fast-growing plants. The diagram on page 85, of an exogenous stem, shows how largely pitted tissue is intermingled with the wood.



Fig. 143, representing a Palm forest, and some of the leading characters of endogenous growth.

Endogenous Stems.—We now proceed to a description of stems which will be less familiar to our readers, and which can usually be examined in museums, or as dried plants only. These are almost peculiar to tropical regions, and are exclusively so if we refer to wooded plants of considerable size—the giant representatives of this class of the Palm tree, with its wonderful utility and beauty.

The class is represented in this country, and in almost all climates, by plants of lesser growth, and more particularly by the grasses; yet, with the exception of the direction of the veins of leaves, they afford but unsatisfactory indications of the peculiar structure of the plant. The most ready illustration will be found in the common Cane and Bamboo; and these will suffice for a sufficient inquiry into this subject.

The term “endogenous” signifies to grow inwardly, and is explained by stating that the bundles of wood sent down from the leaves do not range themselves in layers

on the outer side of the previously-formed wood, but pass down in irregular masses near to the centre of the stem. Such stems, like exogenous stems, are composed of a woof and warp, each of which holds the same relation to the other in both great divisions of trees, and they differ only in their relative proportions and mode of arrangement. Thus the cellular or horizontal warp is proportionally increased in endogenous rather than in exogenous stems; and this, together with the arrangement of the woody fibre into bundles, gives a more open character to the section of the stem.

A section of an endogenous stem (Fig. 144) exhibits the following structures:—First, an external inclosing layer or bark, *x*; secondly, a series of circular lines, which represent the cut surfaces of vascular tissue, *y*; and thirdly, the mesh-work intervening between the bundles, which is the cellular tissue or pith, *z*. We shall consider each of these separately.

Cuticle.—The epidermis, cuticle, or bark, of endogenous stems, differs materially from the analogous structure in exogenous plants. It cannot, in any

normal instances, be separated from the stem, as may be readily seen by attempting to peel a cane. It does not naturally crack and separate as does the bark of our forest trees; but is hard, dense, smooth (usually), non-corrugated, inelastic, but slightly extensible, and is a permanent unchanging structure. Thus, the diameter of such stems is necessarily greatly restricted; and it is in length only that endogenous plants can be greatly developed. It does not consist of a series of layers, which may be detached from each other, and distinguished by various names, but is simply formed of one or two layers—a mass of flattened cells, with bundles of woody fibre intermixed, and connecting it with the internal parts of the stem. The non-extensibility of these layers is not evident until the tree has attained to somewhat of its natural diameter; for the bamboo may appear at first as large as the finger only, and subsequently exceed in circumference a man's thigh. Moreover, a few plants, as the *Dracena* or dragon's blood tree, referred to at page 1, has attained to a circumference of forty feet. Thus, whilst it is true that the width of endogenous stems, as compared with their height, is much less than in exogenous trees, we must admit that the cuticle is extensible, and must infer that its further development is prevented by a degree of expansibility which does not proceed beyond a certain point; or that its further non-development is simply a part of the general law which governs the growth of these plants. It is difficult to agree with the common opinion, that the limited power of expansion, which the cuticle is said to possess, is the cause of the limited diameter of the stem; and it seems more philosophical to assume, that it is only a part of these occurrences which accompany the normal development of these structures.

That the size of the stem remains the same at all periods after its full development

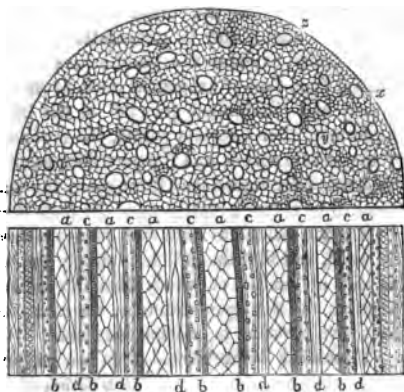


Fig. 144, showing, by a horizontal and perpendicular section, the structure of endogenous stems.

a, z, cellular woof of the stem.
b, d, bundles of vascular tissue.
y, their cut ends.
x, the so-called cuticle or bark.

is quite evident from the fact that twining plants may encircle it for many years without compressing it; but this is begging the question; for if the stem be fully developed, as at first referred to, no further increase of tree is expected. The truth seems to be, that endogens cease to grow at their lower part, whilst growth proceeds above; and thereby the cuticle may have attained to a maximum of extension near to the base, whilst it may be comparatively undeveloped above.

Schleiden explains the peculiarities of the cuticle of endogenous stems, as distinguished from that of exogenous ones, by employing the term "limited growth" to the former, and "unlimited growth" to the latter; and explains them by stating, that in the former, after a certain period, the production of the fast-growing thin walled-cells of the cuticle ceases, and the partitions become thicker; whilst in the latter, the cells are continually reproduced throughout the whole period of growth of the plant. This seems to be rather a statement of the facts than an explanation of them.

It is the fashion to state that endogens have no bark, since none is separable from the wood, and that the cuticle is simply the hardened exposed cells of the stem, with the ends of bundles of woody fibre intermixed. If analogies are truly founded upon function, and not upon structure, we must admit that there is a cuticle or external protective covering to endogenous stems.

Vascular Structure.—This is a mixture of woody fibre and bothrenchym, with the addition of spiral ducts or spiral vessels.

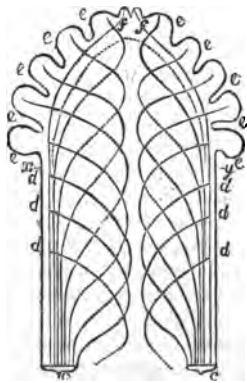


Fig. 145, showing the arciform arrangement of the bundles of woody fibre in endogens (as the Palm), as they pass from the series of interfoliar organs at the head of the stem, and their thin parallel arrangement on the inner side of the bark.

a b, fully developed part of the stem.

d, cicatrices of leaves, with their vascular bundles.

e, bundles proceeding from the buds.

f, the latest-formed leaves—after Schleiden.

If we examine a transverse section of a cane, we do not find a central pith, with wood arranged in layers around it, but a surface marked by fourteen cut ends of round bundles of vascular tissue, set in a cellular matrix. So also on making a perpendicular section, we notice that the surface of the section presents a number of perpendicular defined lines, which may be torn out, and a series of intervening connecting substances. The distinguishing peculiarity of endogens is the arrangement of the woody fibre.

The general direction of the woody fibre is clearly from above downwards; but it is highly probable that it does not descend in straight lines, and that when the tree has attained a tolerable height the wood does not descend directly to the root. As the structure is not indigenous to climes where scientific men abound, the observers have been few; and as the subject is an intricate one, it has not, as yet, been fully elucidated. Mohl is the best authority, and he affirms that the bundles of fibres descend from the leaves in arcs, which direct their convexities towards the centre of the stem. Thus the fibre, in its descent, first passes towards the centre, and thence towards the circumference, until it reaches the bark, or nearly so, when it passes down in a more direct manner towards the root. Each fibre will therefore somewhat represent a hedge-hock with a long handle—that is, have the form of an arc above, and a straight line below. The centre of each arc will not correspond with the central point in the height of the stem, but will be distant

from either end of the arc about one foot and a-half. It is not presumed that all the fibres enter the bark, but that some curl and attach themselves to it, whilst others pass to the roots. Thus the perpendicular section of a Palm would exhibit a series of arcs, intersecting each other, and originating in points gradually ascending as the tree grew in height. These arcs would proceed from every point of the circumference of the stem, and present their convexities towards the centre.

Thus far, the best observers are agreed; but the precise point of origin is still a matter in dispute. That they proceed from foliaceous organs, as in exogens, is certain; but whether from the fully-developed leaf, or from undeveloped interfoliar organs, is undetermined. The former is the opinion of Mohl, and the latter of Schleiden; whilst Muribel occupies a midway position, and asserts that they proceed from an independent part of the growing point, or *Phyllophore*. The successively ascending points of origin of the arcs are explained on either of these theories; for in endogens the foliaceous organs, whether developed or undeveloped, are placed only on the top or head of the stem, and are yearly supplanted by others rising from above them as the stem elongates.

There is, however, a material difference of opinion as to the immediate direction taken by the growing wood, according to the views above expressed. Thus, on Mohl's theory, the woody bundles are formed at the highest point—*viz.* within the leaf itself, and have but one direction, that from above downwards; but on Mirbel's theory, the point of origin is below the leaf, and the bundles pass in two directions—one upwards into the leaf, and the other downwards into the stem. If we adopt the latter theory we must admit that the oldest part of the wood is neither at the top nor at the bottom of each bundle, but at an intermediate spot—a point near to the upper extremity.

It is agreed by all observers, that there is no evident dissimilarity between an exogenous and endogenous stem up to the end of the first year of growth; for in both cases there is a central pith and an external layer of wood, which has been divided into two portions, one of which has applied itself to the bark, and become the *liber*; whilst the other is the true wood, which surrounds the centre. The distinction begins in the following year, when the divisions of the bundles of woody fibre into *liber* and wood does not again take place in endogens; and, as in those plants, the whole wood passes down into the bark, and near to it, the lower part of the stem, as in palms, is much more solid and resisting than the upper part.

The uses of vascular tissue in endogens are the same as those of exogens, but the proportion of saccharine juices which it contains is greater in the former than in the latter. This is a beautiful arrangement for the convenience of those inhabiting hot and often arid countries, where animal milk and water are but sparingly afforded. (See page 24.)

Pith.—The pith in endogens may be said to occupy the whole of the stem, and to form the bed into which the woody fibres pass. If we deny the existence of bark in endogens, we cannot affirm that the pith also forms the cuticle, having first had its cells thickened to render it more resisting. On the section of a stem it will therefore be found to intervene between the bundle of vascular tissue, as exhibited in Fig. 146, and to form the very boundary to the stem itself. In the endogenous plants of our climate, as the grasses, and in many similar fast-growing specimens of hot countries, as the bamboo, the central pith is ruptured, and ultimately absorbed; so that there is a central vacuity, except at the nodes, where a partition of pith still continues.

The uses of pith are chiefly two: first, to supply a soft, elastic, and yielding struc-

here, through which the vascular tissue may pass from the leaves towards the roots and secondly, to contain starch, oftentimes of great purity and abundance, as in the stem of the sago palm (*Sagus Rumphii*).

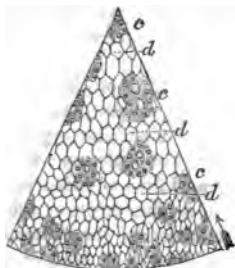


Fig. 146.—Horizontal section of the Sugar Cane (*Saccharum officinale*) showing the cellular structure or pith at *d*, and the intervening bundles of vascular tissue at *c*.

The points in the external characters of endogenous stems, which are peculiar to these structures, are the following:—

First. As a rule the stem does not give off branches, but proceeds either singly or dichotomously (divided into two) from the base to the apex.

Secondly. The leaves are therefore found only at the head of the stem, and surround it by numerous insertions, arranged above each other in a spiral manner. They are

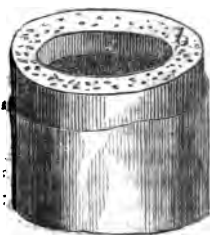


Fig. 147.—A section of the stem of the common Reed (*Phragmites*), showing at *a* the central cavity, and at *b* the solid stem, with the bundles of woody tissue.

usually of large size, and compensate for their paucity in numbers. When their duty has been performed, they wither and decay upon the stem, or ultimately fall from it, leaving a mark called a cicatrix to indicate the points to which they were formerly attached. The succession of leaves takes place from below upwards, and thereby a palm of some years growth presents a series of cicatrices. As the age of the tree cannot be determined by the number of the concentric series of the wood, it is inferred from the number of rows of cicatrices, which indicate the successive seasonal formation of leaves.

Thirdly. From the above reasons, the stem is not conical, but cylindrical, and is full in proportion to its diameter. Not that it is cylindrical, as opposed to conical, to the very apex of the plant, (for the very apex has not so large a diameter as the inferior part,) but since the reduction in diameter is somewhat sudden, and is found only very near to the terminal part of the stem, it is more truthful to state that the figure of the stem is a truncated cylinder than a cone.

In all these respects the stems of endogens are very unlike the stems of exogens.

The Descending Axis or Root.—Having now completed our account of stems, it will be more convenient to state the little which may be necessary respecting roots, before we proceed to a description of the numerous and complex structures which are attached to stems.

We have already stated that the stem and root proceed in the seed from a central spot termed the collum, and that they hence take opposed directions,—the stem ascending, the root or radicle descending. This direction of the root is almost universal; and wherever it is once attained, no power short of the death of the plant can prevent its progress.

As the root naturally seeks to bury itself in a medium much more dense than itself, it is so formed that its extremity has but a very minute diameter, and at that extremity it is composed of the most delicate structure. The vital process of growth enables it to insinuate itself, without injury, between stones and other resisting substances. Thus the root has naturally a conical figure, with its base opposed to the base of the stem,

and the whole plant may be said to consist of two cones, attached by their bases. The thicker part of the root is termed the *caudex*, the minute apex, the *fibrilla*, and its terminal point, the *spongiola*. Both of these parts, as has been proved by experiments, have the power of elongating themselves, but more especially the part near to the free extremity. Our readers may satisfy themselves of this fact by taking any fast-growing root, as of a hyacinth growing in water, and tying a thread around the roots at known intervals, and, after the lapse of a few weeks, ascertain, by admeasurement, the total and relative elongation of the root and its parts. If a plant be selected, the root of which grows in the ground, it will be found that the relative properties of growth of the upper, as contrasted with the lower portion, is infinitely less than in plants growing in water. This is to enable the root to penetrate with less difficulty the resisting medium. In this mode the roots of forest trees are enabled to penetrate the soil for many yards from the base of the stem, so as to enable them to get the water and other articles of food which may not be readily afforded at the base of the stem.

The tissues of which the roots are composed are nearly the same with these of the stem, *viz.*, woody fibre, ducts, and cellular tissue. The woody fibre does not penetrate into the spongiolæ; but is restricted to the parts immediately above it, whilst ducts and cellular tissue we meet with exclusively in those organs. The reason of this arrangement is that the spongiolæ is an organ of absorption as well as of growth, and by it all the fluids which enter the plant are introduced; it is, therefore, not restricted to one point, as the apex of the root, but is found on various parts of it (as may be seen on the side of the radish), whenever absorption can be effected; and it is of the greatest importance, in transplanting trees, to avoid the destruction of too many of these delicate thread-like organs. Some writers restrict the term spongiolæ to the very extremity of the delicate fibrilla, which is somewhat tumefied; and there it is said to consist of a mass of small cells. This is probably the true statement of the case, as may be seen by placing a thin section of the end of a root of the radish under the microscope; and then we must regard the ducts to which it leads as organs destined to convey fluids

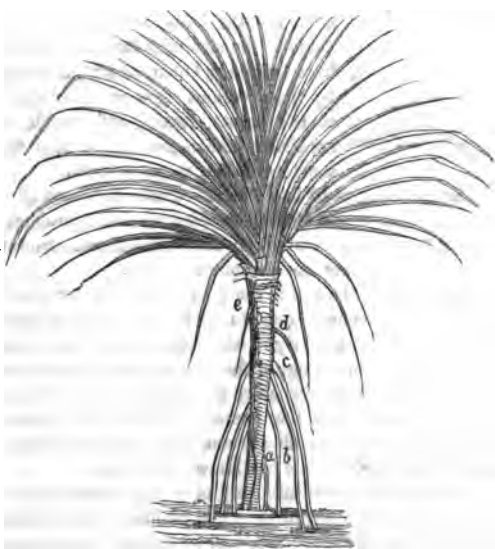


Fig. 148.—The *PANDANUS*, or *SCREW PINE*, emitting aerial roots at *a*, *b*, *c*, *d*, and *e*, which ultimately reach the ground, and give increased stability to the stem.

from the spongiolæ to the caudex of the root. The spongiolæ have also the power to emit from the root effete and deleterious substances. Thus it is said that trees (as a pear

tree) will not grow upon the spot where a tree of the same species recently grew; and that, not because the soil was exhausted, but that a poisonous excrementitious matter had been deposited there by the roots of the former plant.

There are certain plants which emit their roots above the surface of the soil, as the *Pandanus* or Screw Pine (Fig. 148), and the Mangrove tree. Such roots are termed *aërial roots*; since, until they have sufficiently elongated to reach the earth, they remain above the ground. Their natural tendency, however, is to bury themselves in the ground, and they become eventually roots.

Roots vary greatly in figure, and therefore demand special names; the most common is the fibrous, as in the oak and forest trees, where the body of the root is divided into many smaller, elongated, conical portions. If there is but one conical elongation, the root is termed *fusiform*. When the root seems to terminate suddenly at the body, it is termed *premorse*, or bitten off; if it be fleshy, and divided into several globose parts, it is known as *many-headed*, or as *tubercles* in some of the orchids.



Fig. 149.—A fleshy fibrous root.

a. The caudex.

b. The fibrillæ, with the terminal spongioles.

It is often of importance to distinguish accurately between an underground stem and a root; this is chiefly effected by negative evidences. Thus a root has none of the appendages of the stem, such as leaf buds, leaves, scales, scars, and stomata; and in exogens it has no pith. Some roots have the power of forming adventitious buds, but the buds never proceed in a regular manner from fixed points. So also with branches, when they occur; they proceed not from leaf buds, but in an irregular way from any point of the surface. By these various signs we infer that such enlarged parts of plants, as the potato, turnip, and radish, are true stems, although they are situate under-ground, and that they give off the true fibrillæ or roots from their apices or sides.

Appendages of the Stem.—Under the head of appendages of the stem or axis we shall have to consider the respiratory and reproductive parts of plants, such as the leaves, flowers, and fruit, with their subordinate structures, and shall take them in the order in which they appear upon the stem.

Leaves.—The leaf is the type of construction of all the appendages of the axis, no matter how developed soever may be their external configuration. It is therefore not only imperative to a right understanding of other organs that these should be well studied, but a knowledge of the composition of the leaf is the readiest mode of becoming acquainted with the structure of its prototypes. We will, therefore, invite our reader to bear in mind that the immense variety in the figure of the leaf, and in the leaves and other parts of the flower and fruit, does not imply any difference in structure, but that a knowledge of one is a knowledge of all.

The leaf is technically said to be “an expansion at the back of the base of a leaf-bud;” but such a definition gives no idea of its structure. A more tangible definition is, that it is a flattened and expanded stem; for every structure, which enters into the composition of the stem and none other, is present in the leaf. Thus there is cellular and vascular tissue inclosed on each side by a cuticle.

The leaf is, for the most part, a flattened organ, having two surfaces, a *pagina*, a border, a bore, and an apex, the whole of which constitutes the *lamina* or blade; and frequently it is connected with the stem by a foot-stalk or *petiole*. The surface is

commonly marked by a number of ridges which are called veins, and which consist of woody tissue, spinal vessels, and cellular tissue; and they are retained in their position, and the intervening spaces filled up, by cellular tissue. The tissues of the veins are brought in closer proximity in the petiole, which is a small stem, and having passed through it into the stem, one part enters the bark, whilst the other traverses the wood, and penetrates to the medullary sheath at the centre of the stem. Thus every leaf is in direct communication with the stem, and not only so but it is a prolongation of the very pith, spinal vessels, and wood of the stem. The similarity between the leaf and the stem may be carried yet further, for not only do the same structures enter into the composition of both, but in both there is a double set of vessels, one of which conveys the fluid from the root, and the other back again towards the root. The only difference between a leaf and a stem is, that the parts of the stem are more widely distributed in the leaf, and there is an increased quantity of cellular tissue to fit them for their peculiar functions.

We have already, in a previous page, described the cuticle of leaves, with its appendages, and may, therefore, at once proceed to consider the internal structure of these organs.

The veins of leaves are distributed on an uniform plan, and not as a matter of accident, and may be arranged under two heads—*viz.*, the venations of exogens and the venations of endogens. The leaf of an exogen is said to be *reticulated*, and that of an endogen *straight* or *parallel veined*.

The venation of an exogen, as an oak or the holly, consists of a central midrib and a series of festoons, arranged on either side of it (Fig. 150). The large branches proceeding from either side of the midrib are termed *primary veins* (2); and after they have proceeded for some distance towards the edge of the leaf they form a series of curves by which they communicate with each other, and which are termed *curved veins* (3). The curved veins in their turn become trunks, from which other and lesser veins are given off (4), which from their relative positions are known as the *external veins*; while others, of a still smaller size, distributed to the margin of the leaf, are termed *marginal veinlets* (5). Thus far all the veins have proceeded from one source, and clearly belong to one system, being a series of arches placed upon each other, and all resting upon the midrib. But besides these veins there are others, which may be said to belong to an inner system. Thus the *cortal veins* (6) are small branches which proceed from the midrib, at points intermediate to the primary veins; whilst the branches of the primary veins themselves are termed *proper veinlets* (7), and their anastomoses *common veinlets* (8). Such is Dr. Lindley's arrangement, and it is one which merits approbation.

It must not be supposed that these systems of veins can be traced in all leaves; for in the leaves of mosses, and other plants of the lowest class, there are no veins; and in



Fig. 150.—representing the complete venation of an exogenous leaf, as in the ilex or holly.

1. The midrib.
2. The primary veins.
3. The curved veins.
4. The external veins.
5. The marginal veinlets.
6. The cortal veins.
7. The proper veinlets.
8. The common veinlets.

certain thick fleshy leaves, as those of the aloe, the veins are altogether concealed. The first are called *veinetlets*, and the last *hidden veins*.

The venation of endogeneous plants offers a wide contrast to the foregoing, since there are no reticulations, and the veins run in nearly parallel lines (Fig. 151). Such leaves are found in grasses, in palms, and in many exotics grown in hot-houses. They are termed *straight-veined*, and their variations consist simply of a series of primary veins running parallel with, and preceding from, the base of the midrib, and by a transverse arrangement of proper veinlets. An endogenous plant may therefore be distinguished from an exogenous one by the absence of all reticulation in the venation of its leaf.

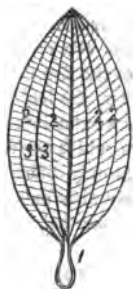


Fig. 151.—The venation of an endogeneous leaf, showing its straight veins.
1. The midrib.
2. The primary veins.
3. The proper veinlets.

There is a kind of exogenous leaf, which closely resembles the straight-veined or endogenous leaf—*viz.*, the *ribbed*, in which three or more midribs spring from, or near to, the base of the leaf; but it differs in having a reticulation of small veins between the ribs. When the midribs proceed from the base, the leaf is said to be *three* (or more) *ribbed*; but when they originate a little above the base the distinguishing term *triply-ribbed* is given.

There are other arrangements of veins, as the *equal-veined* of ferns, the *netted*, the *curve-veined*, the *radiating*, and *feather-veined*; but they are not of sufficient importance to merit further notice.

Whatever may be the precise distribution of the veins, they all tend towards the edge or border of the leaf, and do not there terminate, but are reflected back upon themselves, so as to be accurately applied to the under-surface of the one now described. So perfectly is this effected that an observer could not detect the double distribution of veining in any leaf attached to the tree, and it is only when the leaf is greatly decayed that the two layers become separate. If such a leaf be handled, so that the veins on the two surface be drawn asunder, a distinct division of the structure will be perceived. This division may be accounted for in two ways: first, that there is such a process as that just described; secondly, that both sets are formed at the same time, and; from the earliest moment, are connected together by their extremities; and that as the leaf increases in size both sets of vessels elongate equally at the same moment. It must not be supposed that there is any substance intervening between the two sets of vessels, for it is highly probable that the two sets form but one bundle.

The importance of clearly establishing the existence of a double set of vessels is, that there is clearly a double current; one by which the sap is carried to the leaf, and the other removing it from that organ. The former occupies the upper, and the latter the under surface of the leaf.

We have already intimated that the veins consist of bundles of woody fibre and spiral vessels, with a prolongation of the cellular pith of the stem.

The cellular structure of the leaf is somewhat peculiar, and is admirably adapted to the lung-like functions of that organ. It is divisible into two portions, a *cuticular* and a *parenchymatous* (Fig. 152). We have already fully explained the structure of the cuticle in leaves, and shall only further add, that the cuticular cells vary greatly in size, figure, number of layers, thickness, and hardness; but that as a rule there are two layers of cuticular cells on each surface of a leaf. The parenchyma of the leaf consists

of several layers of somewhat large and thickened cells, which have the power of remaining distended, even when examined under the microscope—a quality which, in some instances, is assisted by the presence of a spiral fibre within each cell (Fig. 44). These cells also very freely communicate with each other (Fig. 152). It may be fairly questioned if that is not a peculiar structure, since it is admitted that the cell-walls are not perfect, and it is certain that they do not collapse when cut open so readily as other cells.

The connexions of the parenchyma are the cuticular cells above and below, and the veins of the leaves which pass through it. It is also, unlike all other cells, exposed to the direct action of the atmosphere, since it receives air through the stomata, which have their chambers within its structure.

The functions of the parenchyma is to receive the juices from the upper layer of veins, and, by the exposure of them to the atmosphere and other influences; to elaborate them, and thus to yield them up to the under or recumbent set of vessels; to be returned to the stem of the plant. It is therefore somewhat the analogue of both the lungs and the stomach in animals, for it performs the functions of both these organs. All the functions of respiration, which are attributed to the stomata, are fairly due to the parenchyma of leaves; for the former bear to the latter only the relation which the mouth and wind-pipe do to the lungs. The parenchyma, in common with the cuticular cells, is usually of a green colour, from the presence of starch and chlorophyle within the cells.

Forms of Leaves.—The form of leaves is very varied, but is permanent in the same species, and is consequently the result of design. Except in a few instances the leaf is never so far modified in form as that the functions of respiration and digestion are interfered with, and therefore the precise necessity for the infinite variations is not clear, except as evidence of that Creator's goodness which cares for the beauty as well as the utility of its works.

The shape or outline of the leaf depends on, or is modified by, the length and relative position of the veins. When the midrib divides into branches, and when all the branches diverge in the same plane,



Fig. 153.—Elm Leaf.

the leaf is flat, and this may be called the normal state of leaves (Fig. 153); when

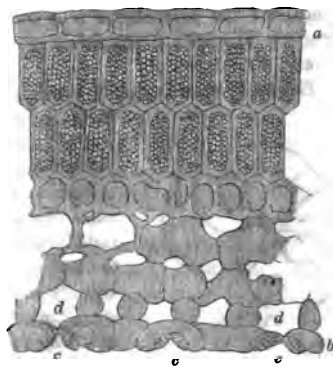


Fig. 152.—A vertical section of the leaf of the *Erionymus japonicus*, exhibiting the cuticular and parenchymatous structures, a, the cuticular cells of the upper surface.

b, the cuticular cells of the lower surface, with stomata at c.
c, the lower open parenchyma, with the air chambers of the stomata, at d.



Fig. 154.—Leaf of *Hydrocotyle vulgaris*.

the veins diverge in different planes, the leaf is orbicular (round), as the leaf of the common sheep-rot (*Hydrocotyle vulgaris*, Fig. 154). In succulent or fleshy leaves, such as the leaf of the house-leek, *sedum*, several pinks, &c., the veins spread in different planes, and the parenchyma is so much developed as to conceal the veins, which consequently are neither prominent nor visible, as they are in the greater number of leaves.

The leaf, when complete, consists of two parts (Fig. 155), *a*, the petiole, or leaf-stalk; *b*, the lamina or blade. The petiole connects the leaf with the branch or stem, and is composed of the unexpanded bundle of fibres, covered by the epidermis; the ramification of the nerves constitutes the skeleton, and the veins and veinlets, with the cellular tissue and epidermis, constitute the entire leaf. When the petiole is not present, the leaf is termed *sessile*. Sessile leaves often partially or entirely surround the stem, and in this case they are termed *semi-amplexical* or *amplexical* (half embracing, or quite surrounding the stem).

The most obvious division of leaves is into *simple* and *compound*. In simple leaves the limb consists of one piece, either quite entire, or variously indented, cleft or divided at the margin. (See Fig. 155, an entire leaf; 154, a crenate; and 153, a toothed or incised leaf.) Compound leaves are composed of one or more pieces, called leaflets, each of which is jointed to the common petiole or rach, as it is termed when the leaf is winged. (See Fig. 156, which represents a pinnate, or winged leaf.)

Simple Leaves.—The shape or contour of the leaf is regulated or modified by the angle of divergence of the lateral or secondary veins, and by their length. When the divergent veins are but slightly distant, and extend from the base to the apex, inclosing only a narrow slip of parenchyma, the leaf is called *linear*. The leaves of grasses are familiar examples of this form. When the veins extend from end to end, and are rather more distant in the



Fig. 156.—*a*, the rach, *b b* *b b*, the four leaflets of the compound leaf.



Fig. 157.



Fig. 158.



Fig. 159.

Fig. 157.—Lanceolate leaf with branching nerves. Fig. 158.—Elliptico-lanceolate leaf. Fig. 159.—Oblong leaf.

middle of the leaf, the *lanceolate* form is produced. In these two forms the veins usually diverge at the base; but in the second, *viz.* the lanceolate form, the relative length of the secondary veins and their wideness of angle produce a lanceolate leaf (Fig. 157). When the secondary or branching veins are nearly of equal length, both at the base and apex, the leaf is elliptico-lanceolate (Fig. 158). The oblong leaf differs from the latter merely in being rather broader at the base and tip (Fig. 159). When the branching veins are nearly equal, the leaf, being obtuse at both ends, is called a rounded leaf.

All these, and many other forms of simple leaves, depend upon the relative proportions of development in the longitudinal and lateral directions; for in every case the apex, or free end of the leaf, is first formed, and then the blade enlarges in both directions. As a rule, the growth proceeds more longitudinally than transversely; and thence, for the most part, leaves are longer than broad. But when it is equal in all directions, the orbicular or rounded form of leaf results. Again, the lateral development never proceeds equally from the base to the apex of the midrib, but is usually greater at the former than the latter, thus constituting the ovate forms of leaves. In a few



Fig. 160.—Obovate leaf.



Fig. 161.—Ob-cordate leaf.

instances, however, the contrary is observed, as in Figs. 160, 161; and it obtains the prefix *ob*—as obovate or obcordate. When development proceeds regularly in these two directions the surface of the leaf is flat, and may be familiarly represented by the palm, or aspect of the hand with the fingers outstretched; but when between any two veins or fingers the transverse development is uneven, a degree of puckering will ensue, as in the leaf of the holly (*Ilex*). In a few instances of tolerably even growth, the

resulting leaf is not flat, but somewhat tubular, as may be imperfectly shown by contracting the hand so that the whole thumb and little finger shall approach each other.

The most frequent variation is the arrest of development at the margin of the leaf. If the lateral development were complete, it is clear that the edge of the leaf would be even or entire; but in many instances it is incomplete, and thence a deficiency ensues



Fig. 162.



Fig. 163.



Fig. 164.



Fig. 165.



Figs. 166, 167.

Fig. 162.—Serrate leaf.

Fig. 163.—Doubly-serrate leaf.

Fig. 164.—A pinnatifid leaf.

Fig. 165.—A doubly-pinnatifid leaf.

Fig. 166, 167.—Hastate and lyrate-shaped leaves.

which gives a tooth-like or crenate appearance to the edges (Fig. 162). Such a leaf is termed *serrated*, *toothed*, or *crenate*. The extent of this deficiency varies much, and

thence the figure necessarily changes. Thus, when it is much greater than that of a serrate leaf, the leaf exhibits a series of lateral prolongations or lesser leaves, the attached end of which is yet distant from the midrib, and the whole is termed *pinnatifid* (Fig. 164). In other instances the arrest of development is equally great at certain points with the pinnatifid leaf, but is not so universal; and thence a lyre-shaped or halberd-head shape results, as in Figs. 166 and 167.

In all these examples the longitudinal system of development is perfect, and the lateral deficiency is so arranged that the edge of the dentation is entire; but in many cases the latter is so modified that the dentations are themselves dentated or serrated. Such leaves are known as *doubly-serrated* (Fig. 163), and *doubly-pinnatifid* (Fig. 165). When the longitudinal system is modified, at the same time that the transverse development is restricted, the leaf puts on a lobed character. Such is represented in Figures



Fig. 168.

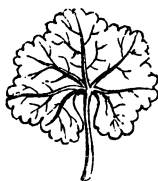


Fig. 169.



Fig. 170.

Fig. 168.—An angular-lobed leaf.

Fig. 169.—An orbicular-lobed crenate leaf.

Fig. 170.—A palmate or deeply-divided lobed leaf.

168 and 169, in both of which the modification is but slightly evident; but in others the division of the lobes is so great that the line of separation passes *nearly* to the petiole, as in the palmate leaf shown in Fig. 170, and *quite* to the petiole and primary veins in the Water Crowfoot (*Ranunculus aquatilis*).

It is not necessary that we should enter minutely into the mode of development of every variety of leaf; and it is probable that we have already given such examples as will enable the reader to apply the principles now enunciated to any other form which may present itself. We shall therefore only name a few other forms which are not unusually met with. The *reniform* or kidney-shaped leaf is represented in Fig. 172; *cordate* or heart-shaped, and *sagittate* or arrow-shaped (Fig. 173).



Fig. 172.—Reniform or kidney-shaped leaf.

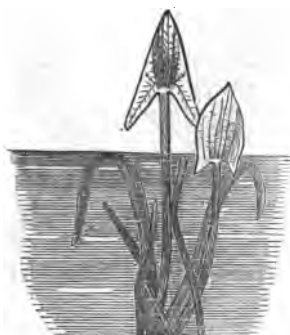


Fig. 173.—Arrow-headed leaf of the *SAGITTARIA* (*Sagittaria folia*).

Leaves are, for the most part, developed *symmetrically*—that is, each half closely resembles the other; but in some instances this rule is not observed. Thus in the *Begonia* the leaf is mani-

festly *unsymmetrical*, having one side far less developed than the other; and in some

of our ordinary trees the transverse development commences on one side whilst it is absent on the other. Such is shown in the elm leaf, Fig. 158.

Compound Leaves have already been defined to consist of several pieces connected together at one extremity by the petiole, the whole of which taken together constitutes the leaf. There is also another explanation of the term, to which we shall refer presently. Compound leaves, then, are lobed or pinnatifid leaves, with the divisions carried down to the midrib or petiole. In their first development they appear as simple leaves only; and in their subsequent progress may still be regarded as simple leaves with extreme subdivision. This may be at once appreciated if Fig. 164 be contrasted with Fig. 173; or Fig. 170 with 175; or Fig. 168 with the Strawberry



Fig. 174.



Fig. 175.

Fig. 174.—A leaf of the *GLIRICIDIA* (one of the *Acacias*), showing pinnate leaves becoming bipinnate, and clearly exhibiting the mode in which many leaves are formed from one simple leaf.

Fig. 175.—A pedate compound leaf of the *HORSE CHESTNUT* (*Fagus castanea*).

leaf, Fig. 176;—in all of which the reader cannot fail to observe that this mode of division of leaves into simple and compound is purely artificial. The divisions of



Fig. 176.



Fig. 177.



Fig. 178.

Fig. 176.—A *STRAWBERRY* leaf, divided into three leaflets.

Fig. 177.—Opposite pinnate leaves, with terminal leaflet.

Fig. 178.—An interruptedly pinnate leaf.

a compound leaf are termed *leaflets*; and, for the most part, each leaflet is of smaller

size, both longitudinally and transversely, than simple leaves. They are subject to great variety of forms; and in their development are guided by similar laws to those already explained in respect of simple leaves.

The most common form of compound leaf is the *pinnate* (Fig. 180), in which there are a series of small leaves arranged on each side of the midrib. When they are in pairs on opposite sides of the midrib, they are said to be *opposite*; and when single they are termed *alternate*. In many instances the leaf is terminated by an odd leaflet (Fig. 177), and the branch is said to be *determinate*; when otherwise, the development of the leaflet has been arrested; and if no flower exist at the end of the branch, it is called *indeterminate*. An intermediate condition is found in such leaves as have small foliaceous organs attached to the midrib between the leaflets; and then the leaf is termed *interruptedly pinnate* (Fig. 178). It is understood that the normal arrangement of the leaflets is *alternate*, as may be inferred from a consideration of Fig. 150; for it is there seen that, although each side is symmetrical, the primary veins (which would form the midribs of the leaflets of a compound leaf) do not leave the midrib at points directly opposite to each other. This is also deduced from the observation, that at the formation of the first leaf at the first node (see page 58), there is no opposite leaf, but that one is subsequently formed at the next node; and hence it is inferred that whenever leaves are placed opposite to each other, as seems to be the rule in the development of the leaflets of a compound pinnate leaf, there has been the suppression of an intervening leaf and node. This suppression is carried to a yet greater extent in the arrangement of leaves in *whorls* (Fig. 179); for then not only are there two opposite leaves,



Fig. 179.

Fig. 179.—A whorl of leaves surrounding the stem.

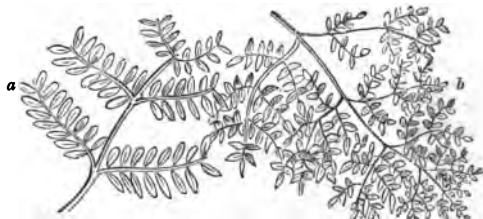


Fig. 180.

Fig. 180.—Representing at *a* the pinnate, and at *b* the bipinnate arrangement of leaves.

but the number is increased to four, six, or more. In such instances there has been an absence of as many nodes as there are leaves, except one. We may also explain the formation of leaves in whorls on the same principles that we have applied to pinnate leaves, *vis.*, that they are all the produce of a divided simple orbicular leaf, as in Fig. 154, in which each leaf incloses one primary vein, whilst a pinnate leaf is in like manner the product of the division of such a leaf as delineated in Figs. 157 and 158. This arrangement of leaves into alternate, opposite, and whorled, is also applicable to leaves, of whatever kind, arranged around the whole branch or tree. In many instances, and especially in the *Umbelliferae*, the pinnae of the pinnate leaf are themselves subdivided, and then the leaf is termed bipinnate (Fig. 180), and is analogous to the doubly-pinnatifid leaf in Fig. 165.

In other instances the leaflets are not arranged in a pinnate manner, but form a kind of tuft, as in Figs. 175 and 176; but even in such cases there is no difficulty in tracing an analogy between them and the whorled form of leaves shown in Fig. 179.

We intimated at the head of this section that there is another form of compound leaf besides that now described, and it is one which is based upon distinct anatomical characters. It is such leaves as are connected with the petiole by means of an articulation or an immoveable joint. If the leaf of an apple or an oak tree be examined, it will be seen that the midrib passes uninterruptedly down into the petiole; but the leaf of an orange presents a transverse line with a slight swelling on either side of it (Fig. 181 *a*), and at this point the blade of the leaf may be somewhat readily broken from the petiole. There is no arrest of circulation at this place, although the separation is easily effected, for the vessels pass uninterruptedly from the petiole to the midrib. It is thus not easy to show how or why such an anatomical peculiarity should exist; for the common opinion, that it is the terminal leaflet of a compound leaf with the lateral leaflets undeveloped, does not much help us. It is also found in the common berberry (*Berberis vulgaris*), and in a few other plants.

We have already stated that a leaf without a petiole is termed *sessile*, or sitting, but when it entirely surrounds the stem it is known as *perfoliate* (Fig. 182), and when it runs down the stem, as in certain thistles, it is called *decurrent* (Fig. 183).



Fig. 182.—A perfoliate leaf.

The *petiole*, or foot-stalk of the leaf, is the assemblage of the veins of the leaf which conducts the juices to and from the stem. As it contains all the vessels of the leaf it must pos-



Fig. 183.—A decurrent leaf, with the midrib adherent to the sides of the stem.

sess two sets of vessels, one devoted to the conveyance of fluids to, and the other from, the leaf. There are also spiral vessels and so much cellular tissue and cuticle as may connect and inclose the vessels in the most compact forms. The figure of the petiole is rounded; but in many instances the upper surface has a channel, and thence is called *gutter-shaped*. In other cases it is perfectly flat, or has processes on its sides which give it the appearance of *winged*; or it is rigid, twisted, or hooked. The grasses and the Ranunculaceae have a *sheathing* petiole, or one which passes down the stem, and is so large as nearly to embrace it. It has at its point of connexion with the blade a little organ found universally in grasses, called the *ligula* (Fig. 184 *a*). The petioles of the leaflets of a compound leaf are termed *petiolules*.

The distal extremity of the petiole is the part first formed in the bud; and when at

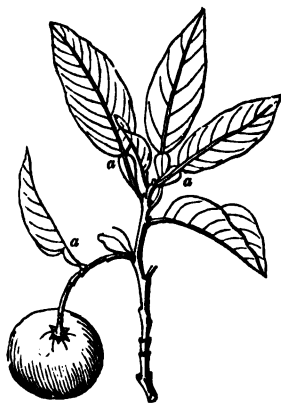


Fig. 181.—The compound leaf of the orange, with the articulation represented at *a*.

length the whole is perfected: it may be so closely connected with the stem that it does not break off when the leaf has decayed, but hangs with the remains of the leaf until the following season. A stem thus covered is said to be *indurated*; but in a majority of cases the petiole falls from the stem, and leaves a mark which is known as the *cicatrice*. The angle between the point of insertion of the petiole and the stem is termed the *axile* or *axilla*, and is the normal position of the leaf-bud and the flower.



Fig. 184.—A stem of a grass, with its leaf.

a, petiole and ligula.
b, sheathing.
c, ligula.

Petioles have several important modifications. Thus in certain so-called leafless plants, as the *acacias*, they assume the function of leaves, and are termed *phylloides*; but that they are veritable petioles is proved by the fact that they bear leaflets at the earliest stage of their development, and have parallel veins, although occurring in exogenous plants. Such are the petioles in the *Dionaea muscipula* or Venus's fly-trap (Fig. 1), in which plant they are expanded laterally, and resemble the true leaves. This modification is due to an unusual development laterally; but there is another in which it proceeds solely in the longitudinal direction. Such are *tendrils*, or spiral-spring-

looking organs, formed sometimes at the free ends of leaves, as in the pea, and at others at the side of the petiole itself, which twist around any fixed body to seek support for the climbing plant. (See Fig. 185.)

There is yet a still more curious modification of development, that in which the petiole enlarges, not only longitudinally and transversely but within itself, by the separation of its vessels and the increased deposition of connecting cellular substances. Thus the petiole becomes a tube, closed at the end by which it is attached to the stem, and open at the other which is opposed to the blade of the leaf. This is the explanation of the formation of the interesting organs known as *pitchers* (Fig. 186*, p. 103)—the pitchers themselves being the petioles, and the moveable lid which closes them being the true leaf. These pitchers have a further interest in the functions assigned to them of containing a watery fluid, and in the unique fact of the secretions of this fluid by certain glands formed within them at their base. In certain plants they are true fly-traps, and thus become direct organs of nutrition to the plant.



Fig. 185.—The tendril, or elongated petiole or midrib.

Stipules are leaf-like organs occurring in pairs at the point of connexion of the petiole with the stem (Fig. 184*).

They are formed at the very earliest appearance of the leaf, and then are seen as two small tumours, continuous with the leaf-like expansion; and since they grow more rapidly than the leaf itself, they at length become one of its protective coverings. They



Fig. 184*.—A pair of stipules, *b*, attached to a stem *a*, at the base of the petiole *d*.



Fig. 185*.—Exhibiting pitchers of various plants produced from modified petioles. *a*, pitcher of *sarracenia*. *b*, pitcher of *nepenthes*. *c*, pitcher of *cephalotus*.

usually assume all the external characters and internal anatomy of leaves (except in size and position), and, no doubt, perform the functions of those organs. In certain pod-bearing plants, as the sweet pea (*lathyrus*), they cannot be distinguished from leaves; and, although they appear as distinct organs in certain roses, they sometimes subsequently become true leaves. In the polygonums and rhubarbs they do not assume this leaf-like character, but appear simply as a membranous, almost colourless, sheath, which surrounds the base of the petiole and the stem, and is known as an *ochrea* (Fig. 186). When they are found at the base of the petiole of a pinnate leaflet, they are distinguished from the stipules of the whole leaf by the term *stipels*. The stipel differs from the stipule in being developed after its leaf, and in proceeding in its growth very slowly. It is occasionally difficult to distinguish the stipule from certain membranous parts formed at the base of the petiole of the common crowfoot and umbellifers; and in most monocotyledonous or endogenous plants, they are not met with.

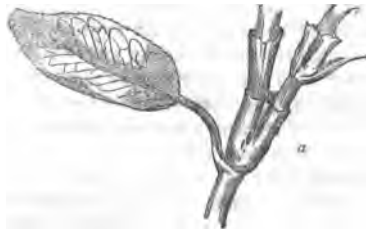


Fig. 186.—Showing the *ochrea*, *a*, or sheath, surrounding the stem in the polygonum, and which is a modified stipule.

We have now completed our account of the fully developed leaf, with its lamina, petiole, and stipules, without having as yet discussed the constitution of the embryo leaf or leaf-bud, because, although the leaf is developed from the bud, and the bud is the first to be formed, yet in the earliest development of a plant the first leaf is produced without a bud, and passes through its course of development before a leaf-bud appears.

The *leaf-bud* is an imbricated or scaly coniform organ, placed in the axis of a leaf, and is a rudimentary leaf or branch formed as the growing season is about to close.

In it, therefore, we rather find the place and the *nidus* in which the leaf will be formed in the coming Spring than the parts of a leaf in a rudimentary condition.

There are only two parts which need attention—the central growing point and the imbricated scales (Fig. 187).

The growing point is composed of cellular tissue, possessing special powers of vitality and growth, and connected with the horizontal system, or pith of the stem. There are no vascular structures within the point itself, but spiral vessels and woody fibre approach near to its base (Fig. 105 *a*). It has a highly important function to perform, for not only is it the point from which all the future leaves must be developed, but it is probably the means whereby the circulation of the sap of plants is again effected after the quietude of the previous winter. To what anatomical part of the growing plant this "pumping" power is to be attributed is unknown, and the vital principle which excites it to action has not been discovered; so that we must at present regard this property simply as being a part of its constitution, and of that of the plant as a whole. This growing point has a certain analogy with the embryo in the seed; inasmuch as both tend to growth and reproduction; but they differ inasmuch that the leaf-bud needs no fertilization for its development, and propagates the individual as well as the species, whilst the embryo imperatively needs fertilization, and continues the species, not the individual. There is also a resemblance be-



Fig. 187.—The leaf bud, with its imbricated scales, *b*, pointed extremity and cicatrix of old leaves, *a*. The growing point is inclosed and hidden by the scales.

tween leaf-buds and bulbs, page 71.

The imbricated scales (Fig. 187 *b*), are called *tegmenta* or coverings, since their duty is to protect the delicate growing point. They are foliaceous organs, and are considered to be identical with stipels. The outer ones are usually harder and of ruder texture than the inner ones or those more immediately surrounding the growing point; and in cold climates a further protection is afforded by a thick downy covering, as in willows, whilst the scales are thinner and smoother in plants growing in tropical regions. All the scales, at least in many plants, are ultimately developed into leaves.

The normal position of a leaf-bud is in the axil of a developed leaf; but, according to the opinion of certain physiologists, the sap has the power of producing buds in any position. It is well known that they have been produced upon the stems of plants and upon the leaves of the *Bryophyllum* (Fig. 188); and the fleshy parts of most plants, as of the bulb of the Hyacinth, may, by care, be compelled to produce buds, and to repro-

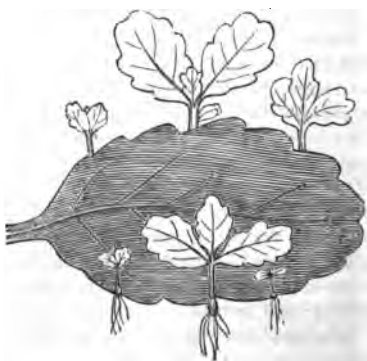


Fig. 188.—The leaf of the *Bryophyllum calycinum*, in which leaves are developed at its borders.

duce the plant. Still such instances must be regarded as exceptional and irregular; and hence the buds so formed are termed *adventitious*.

ORGANS OF REPRODUCTION.

The foregoing descriptions have referred to those parts of a plant which are concerned in maintaining its own vitality and increasing its development, and may therefore be termed *personal*; but there are other parts which have for their functions the production of new individuals, and may thence be called *relative*. Such are the organs of fructification, and they are known generally as flowers, seeds, and fruit. We shall consider these in their order.

The Flower is in part a reproductive organ, with certain protective coverings. It consists of various parts, as the bract, calyx, corolla, stamens, and pistils, in their order, proceeding from without inwards.

The Inflorescence.—A number of terms have been devised to enable us readily to designate the appearance which the whole arrangement of flowers presents upon the flower stalk, and it will be convenient to place them here before we enter upon the consideration of the parts of each flower. Such an arrangement of flowers is commonly termed the *inflorescence*.

The flowers are immediately supported upon the stem in one of two ways; either by a more or less elongated branch, or foot stalk, termed the *peduncle*, or by a flattened more or less fleshy organ, as in the Strawberry, known as the *receptacle*. The *peduncle* differs in no essential respect from the foot stalk of a leaf, its variation being merely that of size and form to enable it to support the flowers. When it supplies the place of a stem, as in the Cowslip (*Primula*), it is called a *scape*; and when it is elongated, and passes in a straight line throughout the inflorescence, it is called an *axis*, or *rachis*, as in Grasses, Fig. 184 *a*. In many instances, as in the *Umbelliferae* (the Parsley), it is divided into a number of lesser peduncles, each one still supporting many little flowers, and the divisions are termed *pedicels*.

The *receptacle* is very commonly met with, and more particularly in the most numerous class of plants, the *Compositae*; but it is there not fleshy, and is sometimes distinguished from the fleshy receptacle of such plants as the Strawberry by the term *thalamus*. The juicy part of the Strawberry is the receptacle, as may be observed by noticing the position of the little seeds which are placed upon its outer surface. The receptacle is the terminal growing point of the stem, and is closely analogous to the flower head of the Arum, Fig. 192.

The arrangement of the flowers upon the foot stalk or receptacle is primarily divisible into two classes—*viz.*, such as have no other intervening foot

stalk, and then are called *sessile* or *setting*, and such as are *stalked*. The examples of sessile inflorescence are the *Spike*, *Locusta*, *Spadix*, *Catkin*, *Capitulum*, and *Glomerulus*.

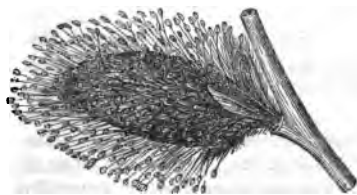


Fig. 189.—The Catkins of the Willow, showing a multitude of flowers sessile upon a common rachis.



Fig. 190.—The Spike.

The *spike* (Fig. 190) is represented by the *Plantago*, and the *locusta* by the common Grass; and they differ from each other, chiefly in that the former has the envelopes of the flower distinct from each other, whilst in the latter the bracts form the sole covering.

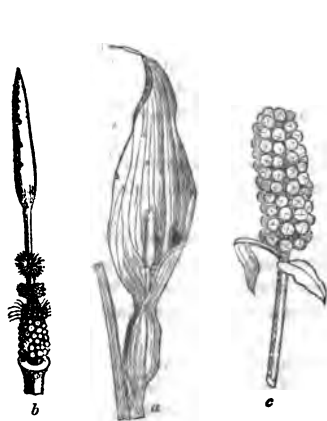


Fig. 192.

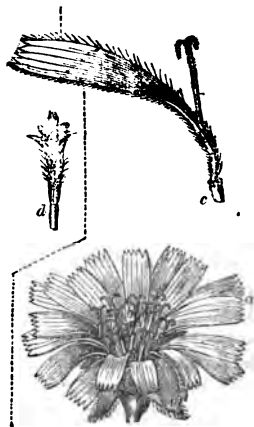


Fig. 193.

Fig. 192.—The inflorescence of the Arum. *a*, the spadix inclosed by the spathe; *b*, the fleshy rachis, or spadix denuded of flowers; *c*, the spadix covered with sessile flowers.

Fig. 193.—A Capitulum in the Composite. *a*, florets of the ray; *b*, florets of the disk; *c*, floret of the ray detached; *d*, floret of the disk detached.

The *catkin*, as in the Willow, so far resembles the *locusta*, that the coverings are not distinct from each other; but it differs inasmuch that the rachis with the flowers falls in a single piece after fructification, whilst the rachis of the *locusta* is permanent. The *Spadix*, as in the common Arum, is an inflorescence with a fleshy rachis, to which the flowers are closely attached, and inclosed in the modified bract called a *spathe*, Fig. 192. The *Capitulum* is a head of flowers sessile upon a receptacle, page 105; and in the Composite the flowers are divided into two classes, the *florets of the ray* (Fig. 193 *a*), which are usually ligulate or strap-shaped, and the *florets of the disk*, or centre, which are commonly smaller, Fig. 193 *b* and *d*. The *Glomerulus* consists of a series of heads in a common involucre.

The second division, or those modes of inflorescence in which the flowers are each supported by a pedicle or stalk, is an extensive field, and comprehends the most beautiful flowering plants. It is divided into the *Raceme*, *Fascicle*, *Corymb*, *Cyme*, *Panicle*, and *Umbel*.

The *Raceme* is the simplest form, and consists of a series of stalked flowers arranged on a common peduncle (Fig. 194), the pedicels being of nearly equal length. When the lower pedicels are so much larger than the upper that the flowers are supported at nearly an equal height, so as to form a kind of head, the terms *Fascicle* and *Corymb* are applied, the former, as in the Sweet William (*Dianthus*), when the expansion of the flower is from within outwards; and the latter when from without inwards. The remaining varieties of inflorescence are somewhat more complicated, since the stalks or pedicels are divided, and bear many flowers instead of one only. Thus the *Panicle* is a

raceme, each pedicel of which bears many flowers; but where the rachis itself divides, and no longer exists as an axis, the panicle is termed *deliquescent*. This latter form gives rise to another variety—the *Cyme* (Fig. 198), as in the Elder (*Sambucus niger*),



Fig. 194.—The Raceme, with its single stalked flowers.



Fig. 195. Fascicle.



Fig. 196. Corymb.



Fig. 197. Panicle.

which consists of a series of deliquescent panicles that have become short and corymbose, with their central foot-stalks meeting at a common centre.—The last form is the *Umbel*, and is divided into two classes, the *Simple* and the *Compound* (Fig. 199). The *Simple Umbel* consists of a number of corymbose branches, meeting at a common point, as in the *Cyme*, and differs from the *Cyme* only in that the branches are corymbs and not panicles. The *Compound Umbel* is distinguished from the *Simple Umbel* by the division of the pedicels, so that they divide and bear other Umbels. The whole head of Umbels is then called an *universal umbel*.

Such is a written description of this somewhat complex and difficult subject; but in order to a ready familiarity with the various kinds of inflorescence, it will be necessary to select the illustrations, and carefully study them with the descriptions,

and after a little attention it will be found that the eye will intuitively, as it were, recognise the leading forms. We now proceed to consider the several parts of which a flower is composed.



Fig. 198.—The Cyme.



Fig. 199.—The Umbel.

The *Bract* is the outermost envelope, and closely resembles a foliaceous organ, and bears the like relation to the flower that stipules do to the leaf. Its colour is more or less green, and as it oftentimes bears much resemblance to a leaf, it is not always readily distinguished from those organs. The rule adopted in making the diagnosis is, that all organs, of whatever size, form, and colour, which intervene between the true leaves below, and the flower above, must be bracts. This definition is too expansive to render the determination of this question easy in every case, and therefore much attention must be given by the botanist to each particular instance of difficulty. Whenever the last leaf on the one hand, and the Calyx (to be mentioned presently) on the other, can be clearly determined, then whatever intervenes must be of the nature of bracts; but whilst it is to be distinguished from leaves only by its lesser size and higher position, and from the Calyx by its foliaceous character and lower position, there must be great difficulty in determining its nature in many instances. In some plants it is necessary to know the number of the divisions of the Calyx, and then to regard all parts external to these, even if almost identical in colour and structure, as bracts.

So long as they resemble leaves it is not needful to attach to them any more particular name than that of bracts; but when they are sensibly modified, it is convenient to give them other designations. Thus in grasses they supplant all other coverings of the flower, and are known as *Glumes* (Fig. 200).

The arrangement of the parts in the flower of the grass is so peculiar as to present much difficulty to the botanist, and consequently various designations have been given to the parts or organs. The three parts which constitute the coverings of flowers are bracts, calyx, and corolla; but, in this great class of plants, either they do not exist, or they are incapable of separate definition. On reference to Fig. 200, it will be observed that there are a series of scales or valves connected by their bases to the common stalk on which they are supported, and having their apices free and oftentimes prolonged into beards or bristles. The outer ones, *b* 1, are large and empty, and are suitably termed *Glumes* or *Gluma exterior*. Within these are a series of similar but smaller scales, attached

in like manner on either side, and opposite to each other, $\delta 2$, and which differ from the outer ones in that they bear the organs of fructification, and each one, in fact, is a separate flower. These have been known as the *Gluma interior*, or more recently as the *pales* or chaff. Within each of these is a third structure consisting of two minute and somewhat fleshy scales, *d*, to which the term *glumella* or *squamul* has been given. Of these three structures it is probable that the first or the external glumes have the greatest analogy to bracts.

The *Cupule* or cup, as in the hazel-nut (*Corylus*), and acorn (*Quercus*), is another instance in which the bracts constitute the covering of the flower.

The *Spathe* is a large bract coloured on its inner side, as in the common Arum, and in palms, and in the numerous plants arranged with them. In this instance there is much evidence that the inner coverings of the flower exist, but are indissolubly connected with the bract.

In the *Compositæ*, or compound flowers, as the rosemary, there are many rows of bracts around each head of flowers on its external surface. This is called the *common involucre*; but besides these there are other bracts placed upon the head between the little florets, and from their resemblance to chaff they are called *paleæ*. In the sedge tribe (*carex*) each floret has two bracts adherent at the edges named *urceolus*, or *perigynium*.

The term *involucre* is employed whenever a series of bracts surrounds a number of flowers. The word *universal* is also added in the umbelliferous plants, as the carraway seed (*Carum Carui*), to distinguish the common involucre of the whole head of flowers, whilst the term *partial* designates the involucre of each little division of the flowers (*umbellules*).

Perianth (Fig. 201) is a term employed to designate such flowers as have the two next coverings, the calyx and corolla, combined. Such is the flower of the tulip and the orchis. In many instances the inner divisions of the perianth are more gaudily coloured than the outer ones, thus indicating the separation into corolla and calyx which naturally occurs, and it is customary to describe the three outer leaves of the perianth as a calyx, and the three inner as a corolla.

The *Calyx* is that covering of the flower which externally is enclosed by the bracts,



Fig. 200.—The arrangement of the flowers in Grasses.
a, A series of flowers arranged on a rachis or stalk.
b, A smaller portion magnified.
 1, The empty external glume.
 2, The internal glume with the organs of fructification.
c, An internal glume enlarged and detached.
d, An internal fleshy scale.

and internally lies in apposition to the corolla. As the bract is usually situate at a distance from the flower, the calyx is in fact the external envelope (Fig. 202). In colour



Fig. 201.

Fig. 201.—The Perianth.



Fig. 202.

Fig. 202.—Showing the calyx, *a*, surrounding the corolla, *b*, and forming the external covering.

and general texture it resembles a foliaceous organ, and thus may usually be distinguished from the corolla. When any difficulty occurs in determining the nature of the coverings of flowers, it is customary to regard the external series as a calyx, whatever may be its appearance, and thus no flower can be without a calyx (except such as are composed of bracts only); whilst many are met with without a corolla. The calyx is evidently subservient to the corolla; for, although it exceeds the latter in size up to the period of the unfolding of the flower, it usually becomes relatively smaller by reason of the growth of the corolla, and, in many instances, in the mature state of the flower, bears no proportion to the corolla in size. The calyx is commonly continuous with the peduncle, and is permanent; but in many instances it is *deciduous*, and falls away on the opening of the flower, or immediately afterwards, as in the poppy and the *Cruciferae*, or pod-bearing plants. When the enlargement of the inner parts of the flower causes the calyx to fall, it usually separates from the peduncle in one piece, and is called *operculate*, except in falling it be ruptured, when it is termed *calyptrate*.

The calyx is originally formed of several distinct pieces, which are termed *sepals*; and when, in its after development, these adhere to each other by their sides, and become but one tube, it is termed *mono-sepalous*; but when they still remain distinct, each part is known as a *sepal*, and the whole calyx is termed *poly-sepalous*. The sepals have all the properties and analogies of common leaves, but have the superadded function of protecting the essential parts of the flower. There is, however, one class of plants in which the calyx has exceptional characters, *viz.*, the *Compositae*, or compound flowers.

The flowers in this class are arranged on a *capitulum*, and are very numerous upon one common receptacle. Each floret is perfect, and therefore has a separate calyx, either rudimentary or developed; which, on account of its membranous character, is termed *pappus*. When its divisions are broad, it is called *paleaceous*, or chaffy. The terms *pilose* (velvety), *plumose* (feathery), and *setæ* (bristles), express various conditions under which it appears in its connexion with the ovary.

The position of the calyx is described in reference to that of the central organ of reproduction, the ovary, and is called superior or inferior, as it appears to arise above or below that organ. But in truth it is simply a question of appearance, for since the ovary is the central and final point in the development of the plant, all other organs must be arranged around and therefore below it (Fig. 203). The calyx is consequently always inferior; but whenever it adheres to the ovary, or the parts surrounding the

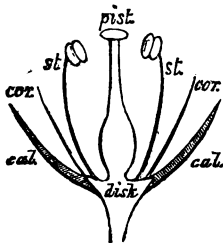


Fig. 203.

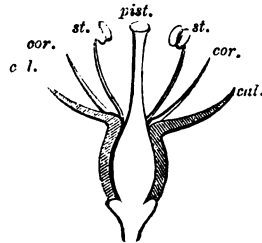


Fig. 204.

Fig. 203.—Representing the relative positions of the parts of a flower, and showing that the calyx, corolla, and stamens must be below the pistil.

Fig. 204.—Showing a condition of flower in which the calyx, corolla, and stamens are said to be superior because they adhere to the side of the pistil or ovary.

ovary, so that it appears as a separate organ only at a point above that organ, it is, in indefinite language, said to be *superior*. Pappus is a superior calyx, since it is closely attached to the ovary. The form of the calyx is a material incident in the description of a plant (Fig. 205), and many terms have been invented to express it beyond those which indicate the number of its sepals, and its permanency or otherwise upon the peduncle. Moreover the form and size of each sepal, and the character of its margin, are always referred to; and the calyx is said to be regular or irregular, according to the uniformity or otherwise of its divisions.

As a rule, the number of sepals has a relation to the number of the divisions of the corolla; so that if there be five of one there will probably be five of the other.

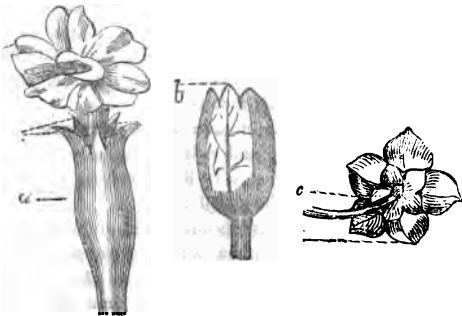


Fig. 205.—Different forms of calyx. a, tubular; b, inflated; c, flattened; all being monosepalous, and the two former having a dentated margin.

The Corolla.—The arrangement of the various parts of the plant upon the stem is agreeable to a definite course in obedience to a known law, as already intimated, commencing with that of leaves and ending with the ovary. It has also been stated that each foliaceous organ is normally formed separately and not in pairs, or in greater numbers, and as the parts are not produced on the same plane or in right lines, but at different heights and in a spiral manner, each one appears to be alternate to the other. When the parts are widely separated this is readily apparent, but when they are brought close together, the observer is disposed to doubt the fact. Yet in such instances they are never so closely arranged that they occupy, or appear to occupy, the same spot, but are placed more or less side by side, and by multiplication ultimately encircle the stem, and are said to be in whorls. Such whorls of leaves oftentimes seem to be on the same horizontal plane; but if such be really the case, it is an exception to the established rule. Thus it will be evident that the whorls of leaves taken collectively, cannot be on the same plane, but must be relatively above and below it; and also that each member of the whorl will be alternate with a corresponding member of the whorl above and below it. Such is the rule, liable to many exceptions; and when, as exceptional cases, leaves are found opposite or in whorls and not alternate, it is assumed

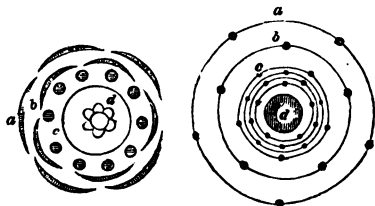


Fig. 206.—Two diagrams exhibiting a ground plan of the arrangement of the parts in the flower, showing that the members of each whorl are alternate with those of inner and outer whorls. *a* represents the whorl of the calyx, *b* the whorl of the corolla, *c* the whorl or whorls of the stamens, and *d* the central pistil or ovary.

that an intermediate leaf, or set of leaves, has been suppressed, or that the opposite or whorled leaves have each really split into two, and thus doubled the original number. This is a difficult subject for investigation, but it is highly probable that the former theory is correct. From this statement the reader will infer, that if the development of the tree begins with the formation of leaves, and ends with the production of fruit, the leaves and all parts between them and the fruit must be situated below the fruit. Thus the bracts are placed above the leaves, the calyx above the bracts, the corolla above the calyx, the stamens above the corolla; and finally, we arrive at the pistil or centre organ

of the whorle. The relatively external and alternate position of the various parts of the flower are well exhibited in the outline sketches in Fig. 206.

A knowledge of this fact is a fundamental one in botany, and enables us, at this point of our subject, to include all the parts within the term *corolla* which lie between the stamen internally and calyx externally (Fig 203.); and, moreover, whenever the calyx and corolla are not very distinct from each other, the inner whorls of leaves are thus appropriated to the corolla.

The corolla, then, is distinguished from the calyx by its normally superior and alternate position; but it has a further characteristic in being unusually gaily coloured. It is that part to which the term *flower* is commonly restricted in ordinary language, and is longer and larger than any other part. It is almost invariably caducous, and falls very soon after the impregnation of the inclosed organs. When it consists of one piece, it is termed *mono-petalous*; and when divided into several pieces, its divisions are known as *petals*; and the corolla is *tri-petalous* or *poly-petalous*, according to the number of its petals. The number of petals is very variable; and whilst it

remains tolerably fixed in the same species, so long as it retains its wild condition, it is apt to vary greatly when the same plant is cultivated. Thus, if we take the rose as an illustration, we find that its normal number of petals is five, as in the hedge rose; but, when cultivated, the number vastly increases, until a "perfect" rose, in horticultural



Fig. 207. A perfect Rose, having nearly the whole of its stamens converted into petals.

language, should present to view nothing but petals (Fig. 207). Whence, then, has the rose obtained its additional petals? Not from new formations, since that would be in opposition to the established law of development, but from a modification of other organs which were originally formed for another purpose. This applies not only to the corolla, but to every part of the flower; and, as a further rule, it may be remarked, that the parts so modified are usually, if not invariably, those which are naturally placed higher on the stem than those into which they become transformed. Therefore the petals are not produced from sepals, and sepals from bracts; but, on the contrary, the bract may assume the place of calyx, and the calyx that of corolla. The newly-formed petals are thence the product of transformed stamens, or the parts of fructifica-

tion which lie immediately within the corolla. In this mode the number of stamens diminishes in proportion as that of the petals increases; and this transformation may readily be traced in any garden rose. The gradual conversion of the one into the other is well exhibited in Fig. 208.

It thus becomes evident that the number of the petals can seldom be employed with certainty as a distinctive mark in the classification of plants. But yet it is not without its value in such plants as retain their natural habits; and the more so when it is known that any increase is usually that of a multiple of the original number, as that five petals become ten or fifteen.

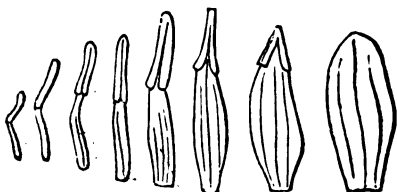


Fig. 208, representing the conversion of stamens into petals, in the Water-lily (*Nymphaea alba*).

In respect of position, the corolla naturally places itself below the ovary (Fig. 208); but whenever it is so attached to the side of the ovary, so that it separates itself only when above that organ, the relative terms of superior and inferior are still employed. Thus all corollas are said to be either superior or inferior.

As a petal is the analogue of the leaf, it is probable that it will have similar parts; and thus we describe the expanded part as the *lamina*, and the contracted part by which it is inserted as the *unguis*, or *claw*. In many instances, as in the rose, there is no unguis, and just as many leaves are destitute of petioles; whilst in many others the claw is several times the length of the lamina, as in the pink, and the petal is termed *unguiculate*. The short claw of the petal of the Crowfoot (*Ranunculus*) has on its inner surface a small gland which secretes honey, and is a true *nectarium* (page 69), but which may probably be a modified stamen.

The forms of the corolla are extremely numerous, as is familiar to every one, and require special designations. If we first examine a monopetalous corolla we find three



Fig. 209.—The corona, *a*, of the Narcissus, surrounding the throat.

parts, which, by their variations, give variety of form. First, there is the expanded portion, which consists of a series of laminae, connected at their margins, and which has its free border more or less indented or divided in such a manner that the divisions are regular or irregular (Fig. 210); secondly, the *tube*, constituted of the united edges of the claws; and, thirdly, the point at which the tube is inserted, or expands into the expanded laminae, which is termed the *fauz* or throat. In a few instances, other parts enter into the formation of a corolla, as the *corona* or cup observed

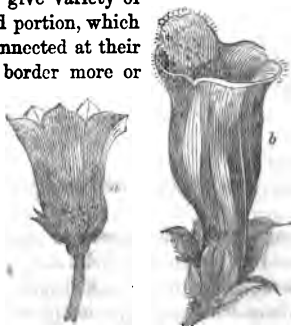


Fig. 210.—*a*, a regular, and *b*, an irregular corolla.

around the throat of the Narcissus (Fig. 209), and the true *Nectarium*, or honey spots, so well known to the honey-bee. A *campanulate*, or bell-shaped corolla (Fig. 210 *a*), as in the Campanula, has little or no tube; and so in like manner with the flattened *rotate* or

wheel-shaped corolla. The tube is greatly elongated at the upper part in the *hypocrateriform* or saucer-shaped corolla (Fig. 212); whilst the *infundibuliform*, or funnel-shaped corolla, differs from the latter chiefly in having the tube expanded at its upper part. There is yet another form of monopetalous corolla, called the *labrate*, and which offers



Fig. 211.—Ringent corolla.

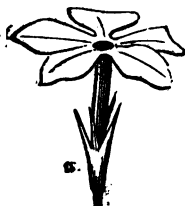


Fig. 212.—Hypocrateriform corolla. *a*, dilate.

the greatest resemblance to the infundibuliform variety. Its distinctive mark is the division of the expanded part into two portions, which in some degree resemble lips (Fig. 210 *b*), and are so placed that one is called the lower and the other the upper lip. When they are widely separated, as in the dead nettle, the corolla is said to be *ringent* (Fig. 211), or *grinning*; and when the upper lip is hollowed and expanded, as in the Monkshead, it is called *galeate*, or helmet-shaped. When, on the other hand, the lips are pressed closely together, as in the Snapdragon, the corolla is said to be *personate*. These are fanciful terms, but yet in many instances give a

familiar idea of the forms to be represented.

The forms of a polypetalous corolla are perhaps less varied than those now described, and, for the most part, will readily suggest the names by which they are designated. Such, for example, is the *cruciate* corolla, which is divided into four parts like a Maltese cross, and having six stamens, four of which are long and two short. There is, however, one very marked variety, which offers some complexity, *viz.*, that of the Pea, and many other plants, called the *papilionaceous* or butterfly-winged corolla (Fig. 213). Such a corolla has also five divisions or petals, four of which are arranged in pairs, and one separately. The pairs form the *carina*, or keel, *a*, and immediately inclose the sexual organs; the *alæ*, or wings, *b*, which lie on either side of the carina; and, lastly, the large *vexillum*, or standard, *c*. The two former names are not inappropriate; but the latter one might have been well exchanged for some term designating a sail.



Fig. 213. Papilionaceous form of corolla.

a, the carina or keel
b, the alæ or wings.
c, the vexillum or standard.

The anatomical structure of the corolla differs in no essential respect from that of leaves. There is, however, a greater delicacy of organization, and variation in the relative proportion of parts. Thus, whilst there are stomata as in leaves, they are fewer, and are accompanied by a smaller quantity of the parenchyma. The veins of the corolla contain a larger proportion of spiral vessels, and less of woody fibre, than is found in leaves.

The colours, even the pearl white met with in the corolla, are due to a colouring matter termed chromule (page 53), placed within each individual cell; and so carefully is this distributed, that adjoining cells may vary considerably in colour. The function of the corolla is that of leaves, with the superadded one of protecting the organs of fructification.

The Stamens.—We now enter upon the description of the essential parts of the flower—*viz.*, the sexual organs, or those parts concerned in the process of reproduction. All the organs which have hitherto been described are accidental, and not essential, since many plants are met with without them, and since their sole duty is to minister to the wants of these central and ultimate objects of vegetable organization. No plant exists which has not organs of reproduction of a higher or a lower grade of organization; whilst many are wanting in every other accessory structure.

The stamens are placed within the corolla, and immediately surround the central



Fig. 214.

a, the central pistil.
b, the stamens included.
c, the corolla.
d, the calyx.

point or pistil, and are regarded as the male organs of reproduction. When longer than the corolla, they are said to be *exserted* (Fig. 215); and when shorter, they are *included* (Fig. 214). Their number is very variable, from one to fifty, and even more; and from the causes already mentioned (page 112), it is not permanent in the same plant, or the same class of plants. It is, however, commonly the same as the petals and sepals; or, if it vary, it is a multiple of that number (Fig. 215). They may constitute one whorl only, which will consist of an equal or double number of the petals, and if of the same number, they will be alternate with them; or there may be several whorls, all of which lie nearer and nearer to the pistil, and follow the same law as the outer whorl. It is not an unusual occurrence to find the stamens placed opposite to, and not alternate with, the petals, or with an inner whorl of themselves. But this is an

abnormal condition, and arises from the suppression of alternate individuals or whorls. This may be readily understood by reference to Fig. 216, in which the stamens are



Fig. 215.—With double the number of exserted stamens to the petals.

double the number of the petals; so that each alternate stamen in the whorl will be alternate with, and each other stamen opposite to, the petal. If, therefore, these stamens be removed, or placed in an inner whorl, which are opposite to the petals, the stamens will then be alternate with the petals; and thus the normal number and position of the parts of the flower be produced. But

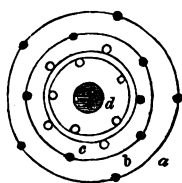


Fig. 216.—Showing a plan of a double row of stamens, *c*, arranged alternately with themselves, and with the petals, *b*, and sepals, *a*.

if, on the other hand, the suppressed stamens are the alternate and not the opposite ones, the flower will become more abnormal by the alteration.

The stamens are also necessarily placed on a plane lower than that of the pistil or ovary, and, therefore, must be inferior, as represented in Fig. 203. But not unfrequently they are said to be superior, from the attachment which they contract with the sides of the ovary (Fig. 204). Three Greek terms have been devised to express this apparent relation in position between the stamens and the pistil—*viz.*, *Hypogynous*, as in the Poppy, when normally placed below the ovary (Fig. 225); *Epigynous*, when growing

upon the ovary (Fig. 218); and *Perigynous* when placed around it (Fig. 217), and attached to the calyx or corolla, as in the Rose—all of which terms, although inaccurate, are in constant use.

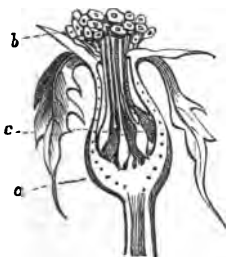


Fig. 217.

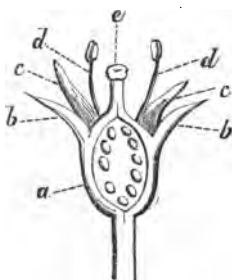


Fig. 218.



Fig. 219.

Fig. 217.—Perigynous stamens.

Fig. 218.—Epigynous stamens.

Fig. 219.—Monodelphous stamens of the Mallow; *a*, forming a tube; *b*, pistils.

The point of insertion of the stamens is into the peduncle, at its terminal point; but sometimes they contract adhesions with themselves, which give such plants a distinctive peculiarity. Thus of ten stamens in the Pea tribe of plants, nine are united together, and constitute a bundle, to the exclusion

of the tenth (Fig. 221 *a*). In the Geranium and the Mallows the whole are united into one body (Figure 219); whilst in the Hypericum (Fig. 220) there are three, four, or more bundles. These conditions are expressed by Greek words, which signify the number of bundles or brotherhoods.

Fig. 220.—Polydelphous stamens.

Fig. 221.—Diadelphous stamens.

Thus the Geranium is *Monodelphous* (one brotherhood), the Pea *Diadelphous* (two brotherhoods), and the Hypericum *Triadelphous* or *Polyadelphous* (three or many brotherhoods). This union of the anthers refers to their lower parts, and is sometimes so close as to have received the name of *columna*, or *gynostemium*, as in Orchids; but there is another which has exclusive reference to the upper—*viz.*, such as is met with in the Compositæ. Like that great class, the number of stamens in each floret is usually five; and they are so connected together at the top as to form a tube, through which the pistil passes (Fig. 222). Such a condition is termed *Syngenesia* (to grow together). Again, there are differences in size as well as position, both accidental and essential. The *accidental* are such as have shorter ones, from an uneven development within the period of growth, either from original tardiness of appearance, or from some subsequent hindrance to growth. This may be well seen in the Poppy, in which the great number of stamens offers a facility for this kind of investigation. In the oxalis, also, thro' them.

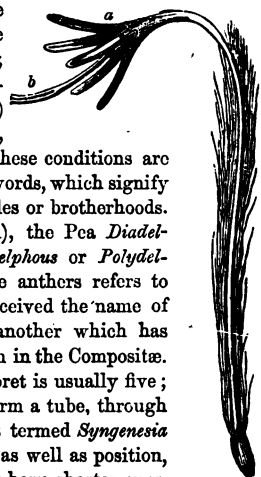


Fig. 222.—
Syngenesia.
a, the stamens united.
b, the pistil passing thro' them.

it is not unusual to find one-half of the stamens shorter than the other. The *essential* differences in size are such as are permanent in the same species; and of these there are two examples. Many flowers with a bilabiate corolla, as the Foxglove and Mint, have two long and two short stamens; whence they are called *Didynamous* (Fig. 223). The cruciate corolla, as in the Turnip and Radish, has usually four long and two short stamens; and to them the term *Tetradynamous* (Fig. 224) is aptly applied.

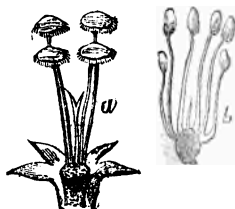


Fig. 223. Fig. 224.

Fig. 223.—Didynamous stamens.
Fig. 224.—Tetradynamous stamens.

The number and arrangement of the stamens was a chief element in the classification of Plants by Linnaeus; and of the twenty-four classes arranged by him we have now referred to five. Eleven others vary simply according to the number of stamens, from one upwards, and are named from Greek words having that signification. Thus *Monandria* signifies one stamen; *Diandria*, two stamens; and so on to *Dodecandria*, which represents twelve or more stamens up to twenty.

Two others—viz. *Icosandria* and *Polyandria*—have an indefinite number of stamens, which in the former are perigynous, and in the latter hypogynous (Fig. 225). Thus no fewer than eighteen out of twenty-four classes are arranged according to the number, length, and place of insertion of the stamens.

We have hitherto regarded the stamen as a whole, but it is naturally divisible into three parts, each of which has special functions and analogies.



Fig. 225.—The Polyandrous flower of the Poppy.

These are the *filament*, *anther*, and its contained *pollen*, the first of which may be entirely absent.



Fig. 226.—Different forms of stamens. *a*, lily; *b*, duck weed; *c*, potatoe; *d*, barberry; *e*, ginger; *f*, sage.

The *filament* is, as its name implies, a thread-like organ, attached by its base to the peduncle, and by its apex to the anther, and latter, and a conduit through which vessels and fluids pass for the nourishment and

growth of the pollen and its case—the anther. It is the analogue of the petiole of the leaf, and like it consists of a bundle of vascular tissue, enveloped in cells, and a delicate cuticle. Its figure is seldom quite cylindrical, but more commonly tapers towards the top, when it is said to be awl-shaped. In a few instances, as in the Meadow Rue, it is the thickest at the top; in others it is spiral, or is bent like an elbow or knee (geniculate), or bifurcates into two branches. In some instances it assumes a foliaceous form, and likewise in most sterile stamens. The

outer whorl is the most subject to this modification, and also to the transformation into petals. Its colour is usually white; but in the Evening Primrose and the Fuschia it is gaily coloured.

The anther is essential only so far as it protects the pollen, which is the male essence in the plant. It consists of a series of cells, which are attached to the top of the filament in three recognizable modes. First, when the base of the anther case is connected with the apex of the filament (*innate*, Fig. 229); secondly, when the union is at the back of the anther (*adnate*, Fig. 231); and, thirdly, when it is so slightly attached, as in grasses, that it can swing freely in almost any direction (*versatile*). This and other facts will be better understood by a reference to the analogies of the anther; for as that organ is the modified lamina or blade of the leaf with its edges so folded that it can inclose contents, it would evidently be expected that in its normal state it should be attached to the filament or petiole by its base.

This view of its construction will also lead us to infer that there are two cells (one on each side of the midrib), with two points of union—*viz.*, one behind, called the midrib, or *dorsal suture*, and one in front, known as the newly-formed *ventral suture*. There will also be one line of separation or division—*viz.*, that lying between the dorsal and the ventral sutures, called the *connective*. Such, it is probable, is the normal type of construction of the anther; but in the extremely modified form in which the leaf thus appears, it is no matter for wonder if the relations of parts should be found much altered. Thus the connective is sometimes absent, and then the anther is one-celled; and, on the other hand, a new septum arises across each cell, and the organ becomes four-celled; and this latter, according to the investigations of Schleiden, is the more common form of anther (Fig. 227).

Its actual construction is best seen at the period of its opening or *dehiscence* for the expulsion of the pollen, and the precise mode of its rupture has been carefully investi-

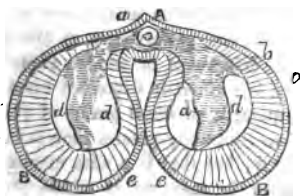


Fig. 227.

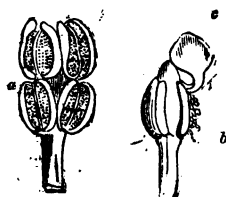


Fig. 228.

Fig. 227, representing a cross section of an Anther. A, the *connective* with the bundle of vessels at *a*; B, the halves of the Anther corresponding with the halves of the leaf; *d*, processes subdividing each lateral half, so as to form four loculi or cells.

Fig. 228.—Exhibiting the ordinary mode of dehiscence at *a*, by longitudinal fissure, leaving the cell open, and some grains of pollen attached; and at *b*, the opening by the rupture of the valve or face of the Anther. *c*, which then curves back, as in the Berberry.

gated. It is certain that the line of rupture runs longitudinally along the ventral suture, and not transversely, except in a few instances, as in the Duck-weed (*Lemna*), Fig. 226 *b*, and that the cells open by a separation of two portions or valves, which

diverge more or less widely from each other, and thus give the appearance of a one-celled organ. In many plants the cells are either unequal, or one only is developed, as in the Sage (Fig. 226 *f*), Canna, and the Arrowroot plant; or after the commencement of the process of development the two cells become confluent, and produce a single cell. As each cell will have a separate line of dehiscence or fissure, a two-celled anther will have two fissures, and a four-celled four fissures, and the latter is probably of common occurrence. But besides the number of fissures, there are other points of disagreement with the general law. Thus in a few instances the pollen is emitted not by a fissure, but by small holes, or perforations; or the fissure does not occupy the whole length of the cell; or the cells burst first into each other, and then have a common dehiscence; or a large portion of the whole face of the Anther comes away in a piece. But however much so minute a matter may vary, it is of importance to bear in mind that it proceeds on a fixed plan, and that its whole organization has a known correspondence with it.

When the line of dehiscence is towards the petals, the anther is said to be *extrorsæ*, and when inwards towards the pistil, it is called *introrsæ*. The lining membrane of the cells is called *Endothecium*, and usually consists of fibro-cellular tissue, whilst the pollen occupies the position of the normal parenchyma.

The Pollen.—The parts of the stamen already described seem to include in their analogies the whole leaf; for the filament represented the petiole, and the anther the lamina, with the parenchym in which the pollen is deposited. But yet there is another and the most essential part of the stamen as yet undescribed, and one which has also its analogies in the leaf itself. This substance is known as the *pollen*, and is the immediate source of fructification. It is a powdery substance of various colours, but more commonly colourless, as may be noticed upon any fully-developed flower. It is that material which is shaken like dust from the flower, and which is not infrequently adherent to the nose when that organ is searching out the sweet odours of flowers.

Its normal position is the anther case, where it remains until it has arrived at a



Fig. 229.—An anther opened longitudinally, and exhibiting pollen grains within its cells.

stage of maturity fitted for the performance of its functions, when it is emitted by the dehiscence or sudden rupture of the anther, or pollen case, and is ultimately deposited upon the free end of the pistil. The quantity of small grains of pollen upon a single stamen is immense—infinity greater than is needful for the fertilization of the pistil; but that is a wise arrangement to insure fructification, despite the influence of winds, the sterility of some of the stamens, and the irregularly-placed pistil. If our readers will examine any half-dozen plants, which may be near to them, in full bloom, and notice the relative height of the pistils and stamens, they will wonder not why so great a waste of pollen has been provided by nature, but that the fertilization should be effected with so much certainty. The improbability of this occurrence is of course greater where the male and female parts do not exist in the same flower; yet not only does it proceed

regularly where there are separate flowers for males and others for females, but in our large forest trees, in which one tree has male flowers only, and another only female flowers. In such cases the pollen is carried by the wind—that very influence which at first sight seemed more likely to cause an entire waste of the

fertilizing material; but in other instances, as in the Bee Orchis (Fig. 230), it is probable that insects and birds are the means of conveying the pollen to the pistil.

Before we describe the influence of the pollen, it is needful to refer to the anatomical characters of that substance. The pollen appears to the naked eye, or with a lens of low power, to consist of a number of particles or granules, of various sizes and figures, which are technically termed cells. The more common figure (as is the case in all cells which lie loose), is spherical, or ovoid; but the most diverse forms have been noticed. Thus they are square in the Bladder (Senna), and triangular in the evening primrose (Fig. 233). In various compound flowers they are many-sided; in other plants they are twisted; and in Dill they are cylindrical. Such, however, are exceptional cases; and whether they may be attributed to pressure, as in



Fig. 230.—An Orchis, with its gynandrous flower.



Fig. 231.—Exhibiting adnate stamens and a pistil elevated much above the stamens.

the cells of cellular tissue, is not known.

When examined with high magnifying powers, as with the eighth of an inch object glass, they are found not to be simple cells, but cells having a cell-wall divisible into two or three layers, and inclosing a turbid-looking fluid, termed *fovilla*. The external layer of the cell-wall is usually itself composed of cells, and is called the *extine*; whilst the inner one is of greater delicacy and extensibility, and known as the *intine*. In some instances, as in the Yew, there is a third membrane between these two, and named the *exintine*, whilst in the Evening Primrose a fourth has been described as the *intexine*. It is probable that all pollen cells have the two former; but it is not indubitable at present that the two latter are at all commonly found.

The *fovilla* usually consists of two portions, which are in constant motion, as may be seen in the garden plant, *Clarkia pulchella*, one of which is larger and more oblong than the other; and as it differs from all other vegetable structures, it is presumed to be the fructifying substance.

Such is the structure of the pollen before it is applied to the stigma; but after it has commenced its fructifying function it exhibits characters unseen before. Thus, immediately it has fallen upon the soft viscid tissue of the pistil, it begins to emit one or more minute processes, which traverse the length of the pistil, and are called *pollen tubes* (Figs. 232, 233). These tubes terminate in the placenta, and thus constitute a medium

of communication between the pollen upon the surface of the pistil and the young embryo. It is presumed that some undetected material is conveyed through the tube, which is the immediate source of fertilization; and it has been observed that the flower has begun to fade immediately after this occurrence, as though the function of that organ had then ceased.

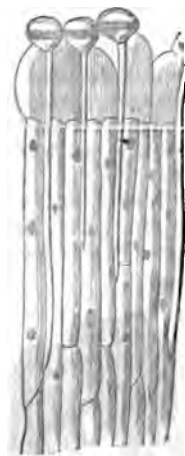


Fig. 232.—Pollen tubes, passing from the pollen, *a*, through the conducting tissue in the pistil of an *Antirrhinum*.

How minute and wonderful are the structures and their functions found in vegetables! equally so with anything known in the animal creation. Thus all the parts of a plant, external to the stamen, are created in perfect subserviency to the functions of that organ; and of the stamen itself, how small a portion seems to be essential. The filament supports the anther, the anther incloses the pollen, the cell-walls of the pollen inclose a little matter, and it is only a part of that ultimate production which is essential to the function for which the plant was chiefly created!

Before leaving this part of our subject we must refer to a substance lying between the true stamen and the pistil, and which is considered to consist of undeveloped stamens. It is known as the *disk* (Fig. 241 *c*), and

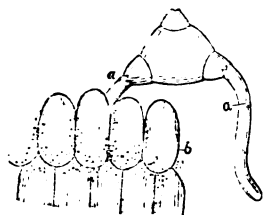


Fig. 233.—Pollen tubes in the *Euthera biennis*.

appears under various forms, according to the so-called superior and inferior positions of the ovary. In the *Compositæ* and *Umbellifera*, with their inferior ovary, the disk is a fleshy body, placed upon it, and oftentimes assumes a scaly appearance. In others, as the *Dead-nettle* and other *labiate plants*, it is found beneath the ovary, and has some resemblance to glands. As it is a mass of undeveloped stamens, its position will always be below the ovary, although it may adhere to that organ, and seem to be perigynous or epigynous.

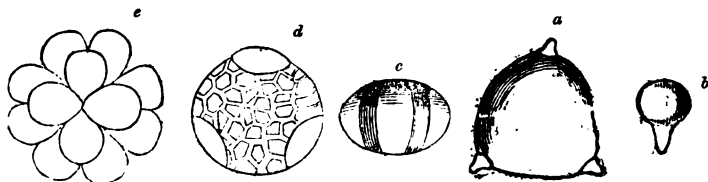


Fig. 234.—Grains of Pollen; *a*, *Fueckia*; *b*, *Scirpus romanus*; *c*, *Salvia*; *d*, *Artemisia fasciculata*; *e*, *Acacia*.

The Pistil.—The pistil is the female part of the flower, and the central point around which all the organs placed upon a branch are arranged. It is usually a complex organ, and oftentimes compounded of many leaves. It is readily distinguished by its central position, and the dissimilarity between it and the stamens in height and form, and more particularly by the absence of an anther at its apex. Occasionally it puts on a foliaceous appearance, as in Fig. 235.

In a majority of instances it is alone ; but not unfrequently there are several pistils so as to constitute one or more whorls. When only one exists, it is termed *Monogynia*, from two Greek words signifying one female. *Digynia* will signify two pistils, and so on (as was explained with regard to the stamens), until we arrive at *Dodecagynia*, which represent about twelve pistils. In this mode eleven orders are added to the classes referred to at page 118 ; and to these one other is appended—viz. *Polygynia*, which signifies an indefinite number of pistils. The number of pistils, as well as of stamens, forms an essential element in the Linnæan classification, and is so employed that a plant with one stamen and one pistil would be arranged in the class *Monandria*, and order *Monogynia*.

The pistil, like the stamen, is divisible into three parts, each of which, as well as the whole, being a modification of the parts of a leaf. They are, first, the free end or apex, called the *stigma* (Fig. 236 *d*) ; second, the dilated base, or *ovary* (*b*) ; and, third, the intermediate structure, or *style* (*c*).

The *stigma* is one of the few external parts met with in vegetables, which are not

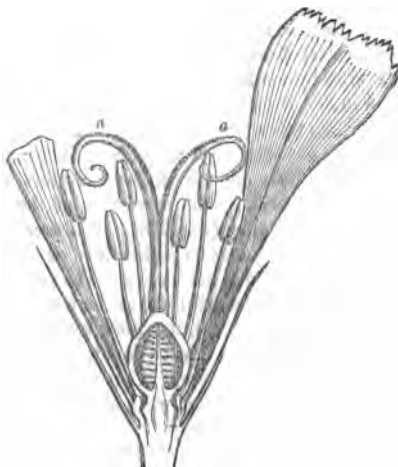


Fig. 224, showing a Pistil with recurved bends, and having a leafy character.

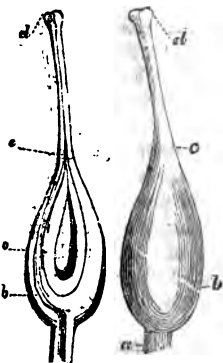


Fig. 236.

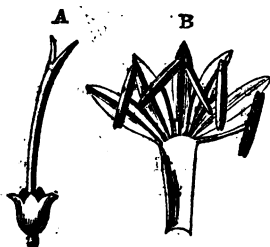


Fig. 237.

Fig. 236.—The pistil in section, showing its turgid stigma, *d* ; the style, with the conducting tissue, *c* ; ovary, *b* ; peduncle, *a*.

Fig. 237.—A, a pistil with notched stigma ; B, versatile stamens.

Fig. 238.—Stigmas with collecting hairs.

covered with cuticle,—at least in the vast majority of instances. Its surface is usually

turgid, and covered with a viscid tenacious fluid. It is either simple or divided into two or more parts, and when divided the divisions for the most part arrange themselves in a whorl. The simple form has also usually a notch in the side (Fig. 237, A), indicating the normal division of even a simple stigma into two parts (see page 126). The anatomical character of the stigma exhibits a series of cells of various sizes, bounded on the sides by another series, which are the cuticular cells. It is in direct connexion with, and in fact is formed by the *conducting tissue*, to be described with the style, and through the pollen tubes pass (Fig. 232). The function of the stigma is that of collecting the granules of pollen upon its surface, and conveying the emitted pollen tubes to the style. It is oftentimes assisted in the collection of the pollen by hairs which surround the style, and which, by the movement of the air, are enabled to sweep the pollen out of the ruptured anther (Fig. 238). Whether it exercises any influence upon the pollen, so as to cause it to emit its pollen tube, or whether the property of emission is exclusively that of the pollen is not known. The part of a leaf with which it corresponds is the very apex of the midrib; and as the leaf is folded inwards on each side of the midrib in order to form the pistil, it is manifest that the stigma will be formed by the two surfaces folded together, and thus be double and lateral (not absolutely terminal). It is present in all fertile plants, except in such trees as the Fir tribe, in which the seeds are naked (Fig. 249), and is stalked when situate at the end of the style, and sessile when the style is absent, as in the Poppy.

Style.—This resembles the filament of the anther; and as its function is that of sustaining the stigma at a convenient distance from the ovary for the reception of the pollen, it may be entirely absent. It varies in form, being flattened and leaf-like in the iris, very thick and sometimes angular in other instances, whilst its most usual character is that of a thread-like or tapering process. It is almost always colourless.

The anatomy of the style is somewhat peculiar, since it not only has bundles of vascular tissue inclosed by a cuticle, as in the filament and the petiole, but there is a superadded structure called the *conducting tissue* (Fig. 232). This tissue is of cellular character, with the cells loosely arranged, and probably is a prolongation of the placenta (page 126). It is connected above with the stigma, and below with the ovary, either at its highest point, as is usual, or at its side, and varies much in quantity. It is analogous to the elongated midrib of the leaf.

The Ovary.—This is the expanded base of the pistil, and is destined to contain the seed, and to become the fruit. It is therefore a most essential part of the organs of reproduction, and is the seat of the latest developments of the plant. It is a hollow organ, consisting of a single cell, or divided into two or more compartments, in each of which one or more ovules or seeds are normally found. The ovules are attached to the ovary by the intervention of a small mass of cellular tissue, called (from its analogue in animals) the *placenta*, and not unusually have an intervening thread of tissue named the *funis*.

The form of the ovary is usually spherical or conical, but sometimes it is flattened and angular. The size varies very much. It is usually sessile, or sitting upon the end of the peduncle; but in a few instances, as in the Passion flower, it is supported on a long stalk.

The analogue of the ovary is the lower expanded portion of the leaf, or, more properly speaking, the whole of the lamina except the terminal extremity of the elongated midrib. This is the type of the construction of the ovary; and one which enables us to determine the conformation of the ovary with considerable accuracy. We shall now

direct attention to this interesting but difficult subject; and in doing so shall consider the pistil as a whole.

If we take up any oval sharp-pointed leaf, such as that of the Poplar, and fold its edges together, so as to inclose the upper surface, we shall have the mode of construction of the ovary. It will then present an internal cavity without any partitions, bounded on each side by a plate or valve, which is the half of the lamina on each side of the midrib. There will also be two lines of union, or sutures, one on the back formed by the midrib, which in the leaf naturally unites the two sides of the lamina, and the other in front, formed by the union of the edges of the leaf. The former line of union is called the dorsal, and the latter the ventral suture. Each ovary will thus have an expanded base and a narrower apex, with a single cavity, two lateral pieces or valves, and a dorsal and a ventral suture lying between them. Such an ovary is termed simple; and as it develops the placenta upon the inner edge of the ventral suture, the placenta will be partly attached to one side and partly to the other, and thus be double. So, in like manner, with the stigma above mentioned;

it is situate at the extremity of the midrib, on the ventral suture, and will be formed by both sides, and consequently be double. The style, when it exists, will have, on its dorsal aspect, the vascular structures belonging to the midrib; and on its anterior or ventral part, the new tissue described as the conducting tissue (Fig. 228), which will either be a mass of placenta or a prolonged placenta. Thus the stigma, conducting tissue and placenta, occupy the ventral suture; whilst the vascular tissues are formed at the dorsal suture.

This description will apply equally to an ovary, which consists of many such leaves, so far as each separate leaf or *carpel*, as it is then termed, is concerned, provided the development of each part proceeds normally. But something further must be said in reference to the arrangement of the leaves or carpels.

If the various *carpels* are so situated that they are not connected with each other, the ovary is called *Apocarpus* (Fig. 240); but if, as is usually the case, they are closely and indissolubly associated, the ovary is said to be *Syncarpous* (Fig. 241). When only two carpels are formed they may be placed side by side; that is, with their ventral sutures having the same direction, or facing each other, when the same sutures will regard each other (Fig. 239). If three or more carpels are formed, they will, in obedience to a general law, be placed in a whorl, and consequently will have all their dorsal sutures directed outwards, and their ventral sutures directed inwards, or towards a common centre. As the carpels will thus be placed side by side, there will be spaces, however small, between them; and thus there will be alternately a carpel and a space (Fig. 243). The space will be bounded by a carpel on either hand, and may therefore be said to have double walls. The space and the boundary walls are together called the *dissepiments*, or *septa*; and when the carpels are united into one mass, the whole may be

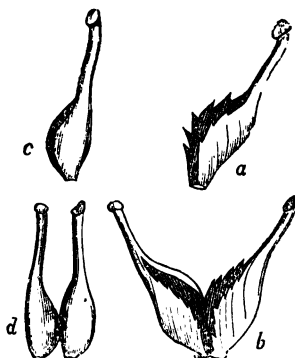


Fig. 239.

c and *d* represent a single and double carpel, with *a* and *b* to illustrate the mode of construction out of a leaf. The lower expanded portion is the ovary, and the free upper end the stigma. There are two carpels; they face each other at *d* and *b*. *e*, the ventral suture; *f*, the dorsal suture.

regarded as one cavity, divided into several compartments by these septa, as in the Orange, which exhibits an ovary of ten carpels. These compartments are called cells; and an ovary made up of many carpels is said to have so many cells, as, for example, a four-celled ovary (Fig. 242). But it often-times happens that the septum becomes imperfect, and thus reduces the number of cells or compartments; and should this be the case with all the septa, a many-celled might be reduced to a one-celled ovary, as in the Poppy. So far, then, a compound ovary consists of a whorl of carpels and a number of cells and septa. Its style will also be compounded of the midribs of so many leaves, and have an equal number of bundles of vascular tissue and lines of conducting tissue. The stigma will be compound, and



Fig. 240.



Fig. 241.

Fig. 240.—Apocarpous ovary, in which each pistil is separate. A, situate within the rows of stamens on the flower; B, detached.

Fig. 241.—A syncarpous ovary, or an ovary in which the carpels are indissolubly united. a, ovary; b, limb of the calyx, united to the side of the ovary; c, the disk surmounting the ovary; d, placenta; e, ovules; f, style; g, stigma; i, peduncle.

represent the same number of leaves, or double the number should each half of the stigma of each be separate; or it may be that the styles and stigma of each carpel remain distinct, and then there will be as many pistils as there are carpels. This



Fig. 242.—A four-celled ovary.

is an arrangement of the ovary found very frequently; but in the Ranunculus or Crowfoot, the Strawberry, and many others (Fig. 240), the ovary is still more complicated. The further complication is due to the presence of two or more whorls of carpels instead of a single whorl. We will consider an ovary of two whorls only, since, if that be understood, the reader will readily comprehend the arrangement of any number of whorls. When two whorls exist, one will be within the other; and thus the dorsal sutures of the inner will be opposed to the ventral sutures of the outer whorl; and in obedience to the law mentioned at page 116, the members of the inner whorl will be alternate with, and not opposite to, the members of the outer whorl. Thus a member of the inner whorl will be immediately in front of the septum, or line of dehiscence, of two members of the outer whorl. This will also apply to the styles and stigmas of the inner as opposed to those of the outer whorl.

Reference is frequently made to two circumstances connected with the arrangement of the carpels—viz., the position of the placenta and dissepiments relatively to the stigma and other parts. As the placenta and stigma are both formed on the inner side of the ventral suture (Fig. 244, c), the position of one may be determined by that of

the other; and should the edges of the ventral suture be open at the point of development of the placenta (Fig. 239), and closed at that of the stigma, there will be two

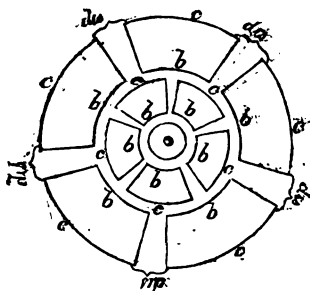


Fig. 243.

Fig. 243.—Showing two rows of carpels, one within the other. *c* indicates the dorsal and *d* the ventral suture; whilst *dis* and the bracket mark the position and composition of the dissepiment or septum. The dorsal suture, *c*, of the inner whorl is opposed to the dissepiment of the outer whorl.

Fig. 244.—Representing the alternate position of the dissepiments, or septa, with the placenta and carpels in an ovary with three carpels, *a*; *b*, is the dissepiment, or the interval between the carpel and its boundary walls; *c*, represents the ovules and placenta at the angle of the carpels, and separated from each other by the dissepiments.



Fig. 244.

placenta to each carpel, and the latter will have a placenta on either hand. So, also, should the stigma be double whilst the placenta is single, the two stigmas will be on either hand of the placenta.

As the dissepiments consist of the interval between the carpels, as well as of the walls which bound it, and, in fact, lie between the carpels, they will be alternate with the stigma, placenta, and carpels (Fig. 243). They will also be perpendicular or longitudinal from the base to the apex of the leaf, and will be equal in number to the carpels, at least when more than two carpels are present, and one carpel cannot have a dissepiment.

Various irregularities occur in the development, or subsequent growth, of the parts of an ovary, and especially in reference to the placenta and septa. Thus, when the placenta are not developed on the inner surface of the ventral suture, but upon the outer surface—that is to say, on the part looking into the space between the carpels—the septa and placenta will be opposite to and not alternate with each other; and then the placenta will be alternate with the stigma. Again, in many cases, as in the Poppy, the Lychnis, and the Violet, the septa are imperfect, and do not extend from the dorsal to the ventral suture. In the Lychnis the portion to which the placenta are attached at the ventral suture remains, whilst the remainder is altogether removed; and thus the placenta, with a small portion of the septa, remain isolated at the centre of the ovary, and are termed “free central placenta” (Fig. 245). In other instances the central part, or the ventral suture alone, is removed; and then the placenta are situated on the

sides of the septa, and are called lateral placentaë (Fig. 246). In others still, the whole dissepiment is removed, and the placentaë are placed near to the dorsal suture (Fig. 247).

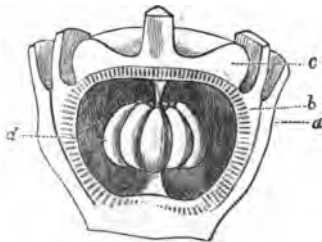


Fig. 245.



Fig. 246.

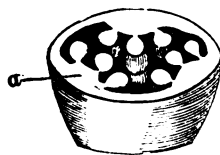


Fig. 247.

Fig. 245.—Representing an ovary with free central placentaë.

Fig. 246.—Lateral placentaë in the *Poppy*; the centre being vacant.

Fig. 247.—Lateral placentaë placed very near to the dorsal suture, as in the *Violet*.

The source of the placenta is still a matter of doubt; but it is either the termination of the growing point, as Schleiden affirms, or it is a modification of the cells of the leaf at the ventral suture. As the position of the placenta is the centre of the very extreme end of the branch, and as it is the point of attachment and growth of the ultimate organ of reproduction in plants, it is probable that Schleiden's theory is both more correct and more philosophical than that which has been more universally received.

Before leaving this part of our subject we should state that the pistil is rarely, if ever, transformed; but occasionally it is itself a transformed stamen, as in the Horse-radish (*Cochlearia armoracia*), and the House-leek (*Sempervivum tectorum*).

The Ovule.—Having now described the house provided by nature for the seed, or embryo plant, we proceed to consider the organs for the protection and growth of which it was designed.

The ovule is the unripe seed, and consequently is the product of the organs of reproduction in the plant. It resembles a leaf-bud in its function, and also in its structure, in so far that it has a central growing point and protective coverings; and in many instances, as the Mignonette and other plants, it has directly produced leaves, without the intervention of a leaf-bud.

The nucleus is the central growing point (Fig. 250, *g*), and consists of a mass of cells, having the chemical constitution of albumen; within it is a cavity containing fluid called the amniotic sac and fluid (Fig. 250, *h*). It is formed at the earliest mo-



Orthotropical.

Campylotropical.

Anatropal.

Amphitropical.

Semianatropal.

Fig. 248.—Representing the relation which the base and apex of the nucleus bear to the hilum and foramen in the normal and abnormal conditions

The dot represents the foramen, the * the chalaza; the outline is the primine, and the opening into it is the hilum at which the vessels enter.

ment of the development of the ovule, and subsequently is inclosed in two coverings or sacs, open at the top, the outer one of which is called *primine* (Fig. 250, *c*), and the

inner one *secundine* (Fig. 250 *c**). The secundine is very delicate, and is larger than the primine, and usually protrudes through the opening, or *foramen* (Fig 250 *b*), and can be examined only at the earliest period.

It has already been stated that the ovule is connected with the ovary by means of a placenta, and a delicate cord, termed the umbilical cord (Fig. 250 *a*); and this is universal, except in such plants as have naked seeds, or seeds and ovules developed without ovaries (Fig. 249). Such are the Coniferae and Cycads, whilst the Mignonette has the seeds partially naked. When it grows from the base, or near to the base, of the ovary, it is called *erect* and *ascending*, respectively; and when suspended from the top, or near to the top, is termed *pendulous* and *suspended*, respectively.

The relative position of the nucleus, coverings, foramen, and funis, is variable, and is important, since it enters into the classification of plants. In the normal position the base of the nucleus is next to the placenta, and is marked by a *hilum* on the coverings at which the vessels enter, whilst its apex is directed to the foramen. Such an ovule is termed *orthotropal*

Fig. 249.—Representing a cone, between the scales of which the seeds lie naked.

(Fig. 248 *a*). When this arrangement is changed only so far that the foramen is curved down so as to approach the hilum, the expression *campylotropal* is employed (Fig. 248 *b*). In other cases the nucleus changes its position; so that its poles are reversed, and its base is removed from the hilum to the point most distant from it, whilst the foramen with the apex of the nucleus is brought near to the hilum. This change is called *anatropal* (Fig. 248 *c*), as in the Apple, Almond, and Cucumber. The terms *amphitropal* and *semianatropal* (Fig. 248 *d* and *e*), indicate that the two ends of the nucleus are transverse with respect to the hilum.

Whenever the nucleus has its base removed from its normal position at the hilum, it is in danger of dying from want of nourishment, since thus it is separated from the placenta and umbilical cord (Fig. 248 *c*), the source of its nutriment; but this is averted by the formation of a bundle of vessels called a *raphé* (Fig. 248 *e*), occupying the ventral suture of the ovary, and passing from the hilum to the base of the nucleus, where it distributes itself in a star-like form, termed *chalaza*. The chalaza, therefore, cannot exist apart from the hilum without a raphé, and both are absent so long as the base of the nucleus is in apposition to the hilum in the membranes.

FRUIT.

When the ovary and its contents, of which we have now treated, have arrived at maturity, they are named fruit, and that quite independent of any edible quality which

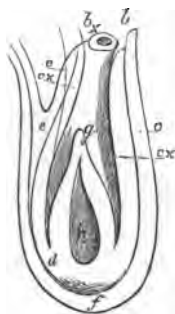


Fig. 250.—Exhibiting the various parts of an ovule.

a, the placenta, with its vascular cord leading into

e, the raphé, which expands at *f*, at the base of the nucleus, and forms the chalaza.

c, the primine, with its foramen or exostome, *b*.

*c**, the secundine, with its foramen or endostome, *bz*.

d, the nucleus, with its apex *g*, and amniotic sac, *h*.

they may or may not possess. At this stage the ovule has matured into a seed, and the ovarium either remains still as a mere containing vessel, or certain parts of it have become fitted to sustain the life of the seed during the earlier periods of its germination. It is to the latter form, as the Apple, that the term fruit is popularly applied; but, in botanical language, the term still comprehends the ovarium with its contents, whatever may be the nature of either.

Fruit, then, consists of various parts—*viz.*, the ovary and its contents; but in many instances there are additions to it, in the form of the remains of some or all of the other parts of the flower. Thus, in the Strawberry and Apple, the calyx remains, and is converted into a succulent substance, or the part of these fruits which is eaten; and in the latter the corolla also remains. The Pine Apple is composed of all the parts entering into the composition of the ovary—*viz.*, bracts, calyx, corolla, and ovary. The Orange (Figs. 181 and 19) is an ovary containing the seeds, and a succulent mass, in which the refreshing juice is placed. On the upper part of this ovary, and at the centre, will be found a circular spot, at which the pistil was formerly attached to the ovarium, and traces of the like attachment may be found upon most fruits; but in certain large classes, as the Labiata and Rosaceæ the style passes from the side, and not from the centre of the superior aspect of the ovary. In a few instances only is the ovarium absent; *viz.*, in the case of the naked seeds of the Coniferae and Cycads (Fig. 249), and in

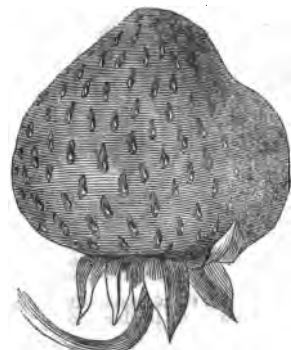


Fig. 251.—The Strawberry, consisting of a succulent calyx.

one or two others, in which the ovarium is ruptured, and the seeds escape long before the maturity of the fruit; but when the fruit has been formed, the term ovarium is no longer applied.

The structure of the fruit is precisely that of the ovarium, except in the instances in which the maturation of the organ has caused certain malformations; and although the former is undoubtedly the rule, the latter occurs so frequently that an examination of the parts is at all times necessary. Thus, on the one hand, the number of carpels seems to be lessened, as in the three-celled ovarium of the Cocoa-nut (*Cocos nucifera*), in which but one cell and one seed remain in the fruit. Such is also the case in the common Hazel-nut, except that the absorption has progressed a step further, and has left but one cell and one seed out of three carpels and six ovules. In a few other cases the number of cells is at least apparently increased, since new partitions are placed across the ovarium, in order to separate the seeds from each other.

The fruit, like the ovary, is also said to be superior or inferior, and for the same reasons—*viz.*, the adherence of the envelopes of the flowers in the latter and not in the former. It is divisible into two distinct parts—the seed and the pericarp.

The *Pericarp* is composed of three parts or layers, one within the other—*viz.*, the *Epicarp* (*a*) or external layer; the *Endocarp* (*b*) or internal layer; and the *Sarcocarp* (*c*) or fleshy substance lying between them (Fig. 259). Thus, in the Apple the outer skin is the epicarp, the juicy part of the fruit the sarcocarp, and the tough thick wall-celled covering to the seeds (Fig. 36) is the endocarp. The same relation is found in stone fruit; and the stony covering of the seed is the endocarp. The epicarp is less subject to

variation than the other structures; but the *sarcocarp* and *endocarp* assume every possible variety of form and consistence.

We have not hitherto referred to the mode of opening of the ovary, since it is not until that organ has attained its maturity that it becomes necessary to make provision

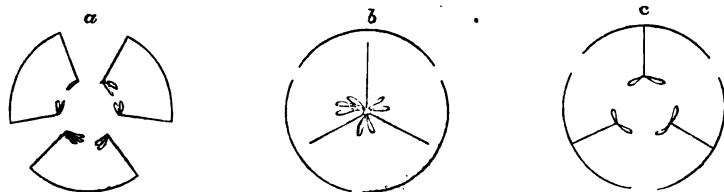


Fig. 252.—Representing the ordinary modes of dehiscence of fruit. *a*, Septicidal, or between the carpels; *b*, septifragal or by the backs of the carpels; *c*, loculicidal, or through the dorsal suture.

for the emission of the seed. This occurs in the fruit, and is a matter of much interest. From the construction of the ovary it may be assumed that the normal mode of rupture of the fruit would be between the carpels; and such a mode of dehiscence, as it is termed, is said to be *septicidal* (Fig. 252 *a*). When the whole back of the carpel comes away from the septa and the ventral sutures, the dehiscence is called *septifragal* (Fig. 252 *b*); and when the septa remain perfect, whilst the ventral sutures become detached from each, and the dehiscence proceeds through the dorsal sutures of each carpel, it is termed *loculicidal* (Fig. 252 *c*). The pieces into which the fruit is thus broken, are termed *valves*; and in the first mode (dehiscence), each valve consists of an entire carpel, whilst in the two latter it is formed by parts of two adjoining carpels. When the fruit is simple, that is, composed of but one carpel, as in the Pea (*Pisum*, Fig. 260), the dehiscence is through sutures, and is called *sutural*, and there are no dissepiments.

In the Scarlet Pimpernel (*Anagallis*) there is another mode of dehiscence, one in which the upper part of the capsule or ovary is detached; and, as the line of separation is horizontal and not perpendicular, the term *circumscissile* has been employed.

Classification of Fruits.—The great variety which exists in the external appearance and anatomical characters of fruit, renders it necessary to devise terms which may serve easily to distinguish one kind from another; and as the number of such terms is very considerable, it has, at all times, been customary to classify them according to their relationships. This has been effected by various writers, with different degrees of success; and, as we cannot devote much space to a consideration of this question, we think it will be most useful to transcribe the newest, and perhaps the most comprehensive, system,—that of Professor Lindley.

CLASS I. Fruit simple. APOCARPI.

One or two-seeded:—

Membranous	.	.	.	.	.	UTRICULUS.
Dry and bony	.	.	.	.	.	ACHÆNIUM.
Fleshy externally, bony internally	.	.	.	.	.	DRUPA.

Many-seeded:—

Dehiscent:

One-valved	.	.	.	.	.	FOLLICULUS.
Two-valved	.	.	.	.	.	LEGUMEN.
Indehiscent	.	.	.	.	.	LOMENTUM.

CLASS II. Fruit aggregate. AGGREGATI.

Ovaria elevated above the calyx:—

Pericarpia distinct	ETÆRIO.
Pericarpia cohering into a solid mass	SYNCARPIUM.
Ovaria inclosed within the fleshy tube of the calyx	CYNARRHODUM.

CLASS III. Fruit compound. SYNCARPI.

Sect. I. Superior: .

A. Pericarpium dry externally:

Indehiscent:

One-celled CARYOPSIS.

Many-celled:

Dry internally:

Apterus CARCERULUS.

Winged SAMARA.

Pulpy internally AMPHISARCA.

Dehiscent:

By a transverse suture PYXIDIUM.

By elastic cocci REGMA.

By a longitudinal suture CONCEPTACULUM.

By valves:

Placentæ opposite the lobes of the stigma:

Linear SILIQUA.

Roundish SILICULA.

Placentæ alternate with the lobes of the stigma:

Valves separating from the replum CERATIUM.

Replum none CAPSULA.

B. Pericarpium fleshy:

Indehiscent:

Sarcocarpium separable HESPERIDIUM.

Sarcocarpium inseparable NUCULANUM.

Dehiscent TRYMA.

Sect. 2. Inferior:

A. Pericarpium dry:

Indehiscent:

Cells two or more CREMOCARPIUM.

Cell one:

Surrounded by cupulate involucre GLANS.

Destitute of a cupula CYPSELA.

Dehiscent or rupturing DIPLOTEGIA.

B. Pericarpium fleshy:

Epicarpium hard:

Seeds parietal PEPO.

Seeds not parietal BALAUSTA.

Epicarpium soft:

Cells obliterated, or unilocular BACCA.

Cells distinct POMUM.

CLASS IV. Collective fruits. ANTHOCARPI.

Single:

Perianthum indurated, dry DICLESIMUM.

Perianthum fleshy SPHALEROCARP-

Aggregate:

Hollow SYCONUS.

Convex:

An indurated amentum STROBILUS.

A succulent spike SOROSIS.

The most common kinds of fruit are the *Pomum* (Fig. 256), or Apple; *Drupa*, or



Fig. 253.

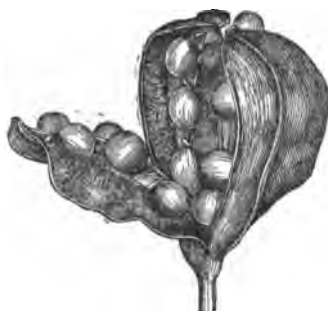


Fig. 254.

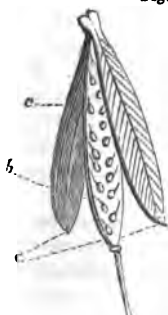


Fig. 255.



Fig. 256.



Fig. 257.



Fig. 258.



Fig. 259.



Fig. 260.



Fig. 261.

Fig. 253.—Siliqua. Fig. 254.—Capsule. Fig. 255.—Siliqua, with valves separate.
Figs. 256 and 259.—The Pomum. Fig. 257.—Strobilus. Fig. 258.—Drupe.
Fig. 260.—Legume. Fig. 261.—Glans.

Drupe, as the Plum (Fig. 258); *Strobilus*, as the Pine Apple (Fig. 257); *Glans*, as the

Acorn (Fig. 261); *Legumen* or *Legume*, as in the Pea (Fig. 260); *Siliqua*, or pod, as in the Mustard (Fig. 255), and which differs from the *Legumen* chiefly in the longitudinal false dissepiment at *a* being present in the former, and dividing the cavity into parts; *Capsole*, as in the Larkspur (*Delphinium*) or Poppy (Fig. 254); and *Bacca*, or two berry, as Currant.

The Seed.—The seed is the mature ovule, and in its internal anatomy maintains a great resemblance to that body. The process of growth and development has, however, induced certain modifications which it is needful to understand, and the more so that the characters of the seed have of late years become of great importance in the description and classification of plants. Like the ovule it consists, in general terms, of a growing point, and contains membranes. The term *embryo* is expressive of the former (Fig. 262 *b*), and *testa*, in a general sense, of the latter.

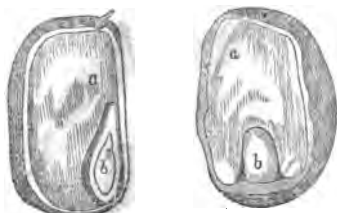


Fig. 262.—Seed.
a, cotyledons; *b*, embryo.

The *testa*, or coverings of the seed, are divisible into three or more layers—*viz.* the outer one, or *primine*; the inner one, or *secundine*; and the third coat, or *terrine*. The detection of these three coats is oftentimes a matter of difficulty; but our readers who have tolerably good microscopes, and who have attained to a certain degree of delicacy of manipulation, need not fear to enter upon it. It will be needful to examine a seed in its fresh state, and to seek the separation of its coats by immersion in water for some hours, and subsequently by the aid of the needles.

The outer integument is commonly smooth, somewhat dense, and resisting; but it may assume every variety of character. The most interesting departure from the established rule is in the instance of the Cotton seed (*Gossypium*), Sage (*Salvia*, Fig. 263), and the *Collomia grandiflora*, in which a large number of shrivelled hairs are attached to this membrane. There is no difficulty in seeing them in the Cotton plant under every condition; but in the latter examples they are inappreciable to the naked eye, until they have been immersed for an instant in water, when they start out, and give a fringed character to the seed. The hair in this case contains a spiral fibre (Fig. 263), which is the cause of its elasticity (pages 14 and 66). In other instances it is largely developed and fleshy. The inner membrane is placed immediately within the outer integument, and itself incloses the most external or third coat. This latter envelope is in immediate proximity to the nucleus or embryo, and is diagnosed from its inclosing covering simply by the non-perforation of its apex.

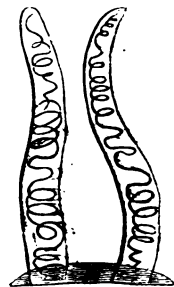


Fig. 263.—Fibres of Sage.

These various membranes are seldom distinct in the seed, and consequently it is customary to speak of the *testa* of the seed rather than of the *primine*, or any other specific part of the covering.

The Nucleus.—This is the growing point already referred to at page 129, as the nucleus of the ovule, and now consists of two distinct parts,—the true growing point, or embryo, which, in the future germination, elongates upwards and downwards to

form the new plant; and, in most instances, one or more masses of albumen destined to supply food to the newly forming plant.

The direction of the embryo in the seed varies as greatly as that of the nucleus in the ovule, and is always determined by similar means—*viz.*, the position of the chalaza, micropyle, and raphé. The terms employed to designate this relation are similar to, but not identical with, those given at page 128 in reference to the ovule. Thus *antitropal* in the seed corresponds with orthotropal in the ovule, the sacs of the ovule not being inverted, but the embryo inverted with respect to the seed, as in the Stinging Nettles. *Orthotropal* in the seed, as in the Apple, is the anatropal of the ovule; *amphitropal* in the seed, that of camphylotropal in the ovules, as in the Mignonette, and have both apex and radicle next to the hilum; and last, *heterotropal* in the seed, is the amphitropal or semi-anatropal of the ovule, and they lie across the seed. In the antitropal and amphitropal forms there will be neither raphé nor chalaza; whilst in the orthotropal and heterotropal varieties both these parts will be present.

The above is indicative of the relation which the embryo bears to other parts of the seed; but there is also a relation which the whole seed has to the fruit of which it forms a part. The seed is termed *ascending*, when the direction of its apex is that of the apex of the fruit; *descending*, when the contrary, or towards the base of the fruit; *centrifugal*, if towards the sides; and *centripetal*, when towards the axis of the fruit.

The albumen varies greatly in quantity, as may be seen by contrasting the split Pea with the white of the Cocoa-nut. It also offers great diversity in solidity, from a mass of jelly-like consistence, to the hardest ivory, as in the Ivory Nut (Fig. 38) in its dried state. It is not present in all seeds, and in many is so minute in quantity that the microscope alone can detect it. Wherever it exists, it immediately surrounds the growing point. Its structure is cellular, as shown in Figs. 37, 38, 39, and others, as may be readily proved, by placing a very thin portion of a green pea under the microscope. When it is met with in the embryo sac (page 129) it is called *Endosperm* (within the seed); and when it constitutes the nucleus it is known as the *Perisperm* (around the seed). Sometimes it is placed near to the chalaza; but it never occupies the position of the membranes. In *Dicotyledonous* plants, as the Pea, the seed readily separates into two halves, which proves that the mass is divisible into two lateral and symmetrical portions, termed *Cotyledons*; or seed-leaves (Fig. 262). In *Monocotyledonous* plants, as the Palms, the albumen cannot be divided into parts, and hence the terms *Monocotyledon*, or one seed-leaf (Fig. 264); and in certain plants it is so reduced in quantity that the seed is termed *Acotyledonous*, or a seed without cotyledons. These terms are of great moment, and of constant employment, since the two former correspond to the exogenous and endogenous divisions of plants referred to at page 81, *et seq.* All flowering exogens, or nearly so, are *Dicotyledons*; all endogens, or nearly so, *Monocotyledons*; and all flowerless plants, *Acotyledons*. The arrangement of the parts in the embryo varies in the classes just mentioned, as might be expected, when in germination one puts forth no seed leaves, another only one, and a third two. The direction of the Cotyledons is usually straight; when two or more exist, they are placed face to face. They are said to be *incumbent* when they are folded with their back upon the radicle, but *accumbent* when their edges occupy that position.



Fig. 264.—The Monocotyledonous seed of the Grass-after-germination has begun;
c, cotyledon;
p, plumule;
r, radicle.

only one, and a third two. The direction of the Cotyledons is usually straight; when two or more exist, they are placed face to face. They are said to be *incumbent* when they are folded with their back upon the radicle, but *accumbent* when their edges occupy that position.

The seed of a Dicotyledon, as the Pea or Apple, presents the following parts (Fig. 265): *two Cotyledons*, or seed-leaves, *a*, at the upper part, within the base of which is a minute point, destined to become the stem, named the *plumule*, *b*; and at the bottom of the seed is the *radicle*, *c*, having dimensions larger than those of the plumule, and separated from the Cotyledons by an unseen line, the *caulicule*. Sometimes the Cotyledons are absent, or cohere into one mass, or divide into a greater number, as four in the Cruciferae, and double that number in some of the Coniferae.



Fig. 265.—The Seed of the Garden Bean. *a*, cotyledon; *b*, plumule; *c*, radicle.

An approach to the condition of a Monocotyledonous seed, is seen in such Dicotyledons as have great inequality in the size of the Cotyledons; so that one of them is scarcely perceptible. In this class (Monocotyledons, represented in this country by the Grasses), there is no such distinction of parts as that now referred to; but the lower part of the seed emits a number of radicles (Fig. 264 *r*), whilst from the upper part the thread-like green plumule, *p*, is emitted. Thus the growing points are sheathed by the embryo, which remains within the testa throughout the process of germination. There are many exceptions to this description; but they do not materially invalidate the rule now given. Monocotyledonous plants are as exclusively endogenous (p. 86) as dicotyledonous are exogenous in their general structure.

There are certain plants in which distinct Cotyledons have not been discovered, and hence have been termed *Acotyledons*; but this would not be a correct mark of distinction for the members of the two classes now described, since it is probable that there are parts analogous to Cotyledons. The true diagnostic is, that in these plants the germination does not proceed from fixed points, as the plumule and radicle, but indifferently from any part of the surface of the seed. This is the condition of the embryo in the great class of plants to which we shall presently refer—*vis.*, the flowerless plants.

There are yet one or two points to which reference must be made, before we conclude this account of the seed. The *Amnios* (Fig. 250) is a fleshy bag surrounding the embryo in many seeds, and consequently lying within the innermost integument. It has also been termed the Vitellus, or Yolk-bag, and it probably performs an analogous office in the sustentation of the embryo.

We have already referred to the hilum and other vascular parts of the ovule and seed, and need here only to state that the hilum is the umbilicus, or the spot at which the vessels from the placenta enter the seed. In many plants it can scarcely be seen, whilst in others it is of a dark colour, or is very large, as the Pea, Bean, and Horse-chestnut. The micropyle, or foramen, is the opening in the seed to which the radicle is always directed, and may be at the end of the seed opposite to the hilum, or the two may be close together, as in the Pea; or it may occupy other positions, as shown at page 128, in reference to the ovule. Its position determines that of the radicle, and consequently is of importance. The chalaza and raphé have precisely the same indications in the seed as in the ovule; but the latter is always distinctive of the face of the seed when the figure of that organ does not render the determination of that question easy.

The *placenta* is the cellular expansion by which the seed is attached to the ovary, and brought into direct connexion with the sexual organs of the plant through its prolongation—the conducting tissue of the style.

The *funis*, or umbilical cord, when it exists, connects the hilum of the seed with the placenta, and conveys the vessels to the ovule and seed.

The *aril* is known familiarly to our readers by the spice called mace, which is the aril of the nutmeg, as may be determined by an examination of the preserved fruit. It presents a great variety of forms and characters in various plants, and oftentimes it is difficult to distinguish it from other structures; but here, as in the case of bracts, negative evidence is of value, and supplies us with the expression, "that everything proceeding from the placenta, except the seed, must be an aril." It is not of large size, except in fully developed seeds. It is closely applied to the outer integument both of the seed and ovule, and in its analogies has been regarded as an ovulary leaf. Arils are divided into two classes—*viz.*, true and false arils, the distinguishing mark being, that in the former the micropyle or exostome either is covered, or would be covered, by the aril, if it were sufficiently extended; whilst in the latter the micropyle is at all times free. It is probable that the aril of the nutmeg belongs to the latter class.



Fig. 265*.—Aril of Nutmeg.



FLOWERLESS PLANTS.

There yet remains, before we conclude this first division of our subject—*viz.*, the structure of plants—to mention a few special modifications of those organs now described as they are found in the flowerless plants; and in doing so we beg our readers to bear in mind, that they are not new structures but modifications of those belonging to flowering plants. There is, however, the most marked line of demarcation between flowering and flowerless plants, both in their minute composition and their external configuration; and we might almost venture to affirm, that we have here an exception to the rule, that nature ascends and descends by imperceptible degrees. There is, however, no new element in structure, in this lower division, than has already been described in reference to the flowering plants; so that the existing diversity is due to the number and arrangement of these elements in the general fabric.

It is customary to consider flowerless plants as more lowly organized than those which bear flowers, although it is through them that the vegetable kingdom approaches the animal. This seems paradoxical, seeing that the animal kingdom is manifestly of a higher grade than that of vegetables; and proves that, from the highest members of the animal kingdom, we do not pass through the lowest to the highest vegetables (as would be the case were the views commonly received properly carried out), and thence to the lowest plant, but that the well-defined members of both kingdoms are wide as the poles asunder, whilst the lowest members are so intimately associated, that it is yet undecided whether they belong to the animal or the vegetable kingdoms.

There is reason, however, in considering the flowerless plants as the lowest members of the class, since their organization is more simple. Precisely so, also, in respect of animals;—and thus the two kingdoms may be likened, not to one cone with an artificial line drawn across it at some undefined point, but to two cones with their apices connected, and their expanded part, or base, at either extremity.

The great point of dissimilarity is that connected with the organs of reproduction; and the question of sexes, and their product, has ever been, as it now is, the bone of contention. That every member of the whole is endowed with the faculty of reproduction is perfectly evident; but the precise mode in which it operates, and even the immediate seat of its operation, is shrouded in mystery. This, however, is only the counterpart of the condition of the lowest animals; and therefore the one is no more matter for wonder than the other. In both kingdoms the lowest examples have abundant power of reproduction; but the distinction of sexes is not evident. When, therefore, we affirm that there is nothing new in the class of flowerless plants, we mean that every part of the structure has its analogue in the higher division of the vegetable kingdom.

The flowerless plants are numerous and very varied, and comprehend chiefly the *Ferns*, *Club-mosses*, and other kinds of *Mosses*, *Lichens*, *Mushrooms*, and *Sea-weeds*.

Ferns.—This extensive class of plants is known in this country only by herbaceous varieties, or such as have their stem or root in the ground, and present to view a series of leaves only (Fig. 266). But in hotter climes the stem is above ground, and often attains the height of fifty or sixty feet, and a diameter larger than a man's thigh (Fig. 270). The following are their chief anatomical peculiarities:—

The leaves are termed *fronds*, and they bear the organs of fructification in little cups or receptacles on their edges, or on their under surface (Fig. 267). These exhibit

little masses of granules, of defined forms, termed *sori*, and consist of a containing organ called *sporangia*, *theca*, or *capsules*, surrounded by a ring (*gyrus*, or *annulus*), and a

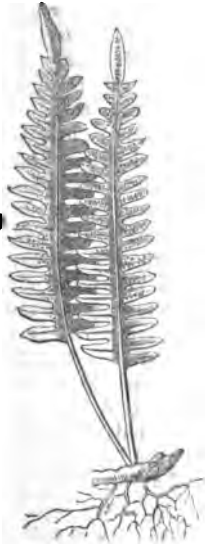


Fig. 266.

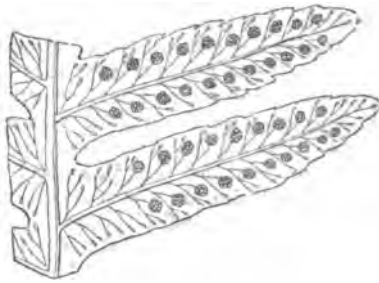


Fig. 267.



Fig. 268.

Fig. 266.—A Fern, *Polypodium Vulgare*, as it grows in our climate.
 Fig. 267.—Fructification in the *Polypodium*.
 Fig. 268.—Sori emitting spores.

number of contained cells, termed *spores* or *sporules*, from which new plants are directly produced. Thus the organs of fructification may be likened to the ovary with its contained seeds, and doubtless this is their true analogy; but to the naked eye they have a greater semblance to the anther with their contained cellular specks of pollen; and this latter idea is further strengthened by the fact that the spores, as well as the pollen, are produced on and from the cells of leaves. The sporangia burst with elasticity; but this property is possessed alike by both anther and ovary. There can be no reasonable doubt but that they are the female organs or ovaries, with the spores or seeds.



Fig. 269.—The fructification of the *Ophioglossum Vulgatum*, showing the transverse slits, *a*.

There is much difficulty in determining what are the male organs, if any, existing in Ferns. Some have referred them to the articulated hairs which are found surrounding the sporangia; and others again have imagined that the layer of epidermis which covers the sporangia in many Ferns, called *indusium*, may be connected with that function. Nothing certain, however, is known.

There are no sporangia in that division of Ferns known as the adders' tongues; but the whole leaf is rolled up on either side of the midrib, and becomes a containing organ. At maturity the leaf opens by transverse valves, and emits the spores (Fig. 268).

The foot-stalk of the frond is called the *stipes*, and consists of bundles or plates of hard woody fibre and scalariform vessels, connected together by cellular tissue, which pass down into the stem within the bark, and appear to form a part of the zones of wood.

The arrangement of the parts in the stem of the Tree Fern is very peculiar; and although it has no close resemblance to either the exogenous or the endogenous arrangement, it seems to be more closely allied to the latter. Thus the rind or bark consists of one or two layers only of cellular tissue, and is marked by the cicatrices of leaves or fronds, arranged somewhat irregularly, and at considerable distances below, but regularly and closely near the apex of the tree, showing that its leaves are produced at the head only, and in successive clusters. Again, a large portion of the transverse section of the trunk is seen to consist of cellular tissue; and through this the wood

passes. The points of resemblance to exogens are, that its centre is occupied by a mass of scalariform (Fig. 71) and large spiral vessels, which in some degree may represent the medullary sheath; and the wood is arranged in circles, but only near to the bark, and the circles have a wavy outline. These pass up into the fronds, or rather are sent down from the fronds; and as the fronds surround the stem, the bundles sent down from them lie side by side, until they form a circle. There are, moreover, lines of communication between the medullary cellular tissue and the bark, which are the analogues of the medullary rays.

There is a peculiarity in the growth of the Tree Fern—*viz.*, that the interval between the cicatrices enlarges as the size of the tree increases, showing that the



Fig. 270.—Tree Fern, forty feet high, growing in the moist climates of small tropical islands.

stem of the tree increases in height, not only at the apex for the time being, but afterwards in the body of the trunk (Fig. 270).

As there is no definite growing point in the sporule, its germination must differ widely from the exogenous and endogenous forms of plants. The sporule, after extrusion from the sporangia, bursts its envelope, and emits a leafy expansion from its centre, which subsequently forms a bud, and from thence a plant.

This subject has been discussed with much judgment by an eminent English botanist, Mr. Henfrey, who has given the following account in the *Gardener's Magazine* for 1851, p. 23 :—

"The germinal frond must be taken very young, while yet not more than one-eighth of an inch in diameter, and before any sign of the first leaf appears



Fig. 271.



Fig. 272.



Fig. 273.



Fig. 274.



Fig. 275.

Figs. 271, 272, 273, 274, 275.—Successive stages of development from the spore (Fig. 271). In Fig. 275 are seen two of the antheridia.

rising from its upper surface. The little frond will then be found in the shape of a rounded

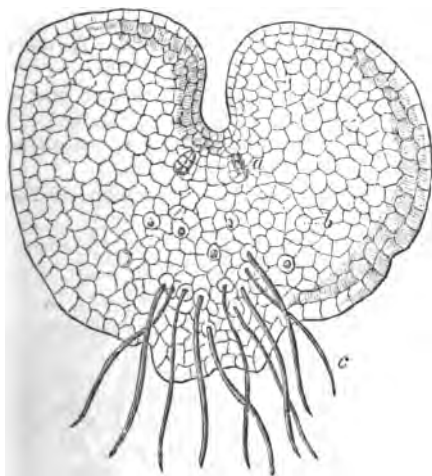


Fig. 276.

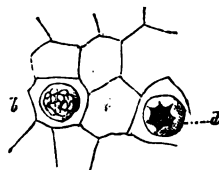


Fig. 277.

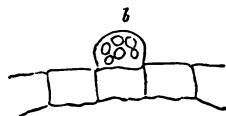


Fig. 278.



Fig. 279.

Fig. 276.—A germinal frond (it is a simple cellular plate like the leaf of a Moss): *a* are two ovules; *b* a number of antheridia; *c* root fibrils.

Fig. 277.—A more highly magnified view of a piece of the frond with two antheridia, one containing the vesicles (*b*), the other burst (*d*).

Fig. 278.—Side view of *b* in the last figure.

Fig. 279.—The same bursting to discharge the vesicles, which again discharge the spiral filaments *c*.

or heart-shaped disk, formed of delicate green cells (Fig. 276); a single layer, except in

the middle, having been gradually developed into this form through the stages represented in the annexed figures (Figs. 271—275). To see the peculiar organs, the disk-like cellular plate must be carefully laid face downwards upon a slip of glass, and washed clean, gently removing the grains of soil, with a camel-hair pencil, from among the rootlets. When placed under the microscope, a number of projecting cells (Fig. 276 *b*) are generally found scattered about the frond. These are seen to be again filled with minute vesicles (Figs. 277 and 278), which escape by the bursting of the protruding cell, either spontaneously or by slight pressure on the glass covering the object (Fig. 279). As the vesicles emerge they burst also, and from them springs out a spiral thread-like body, thickened at one end, and furnished with cilia, as represented in the woodcut (Fig. 280). These, the so-called animalcules, swim about with great rapidity



Fig. 280.



Fig. 281.



Fig. 282.



Fig. 283.

Fig. 280.—One of the spiral filaments, or animalcules, more magnified.

Fig. 281.—Side view of an ovule.

Fig. 282.—The summit of the same, seen from above.

Fig. 283.—Side view of an ovule from Suminaki, representing the embryo-cell at the bottom of the cavity.

shooting forward, and continually whirling round on their own axes. To see them clearly, their motion must be stopped by adding a little solution of iodine.

On the thickened part of the frond, near the notch, are to be found, in most cases, not always, cellular structures of larger size, and more complicated (Fig. 281). They consist of conical papillæ, with cellular walls, containing a cavity in the centre, as represented in the Figures 282 and 283.

In Club Mosses (*Lycopodium*), the containing reproductive organs are also called thecæ,



Fig. 284.

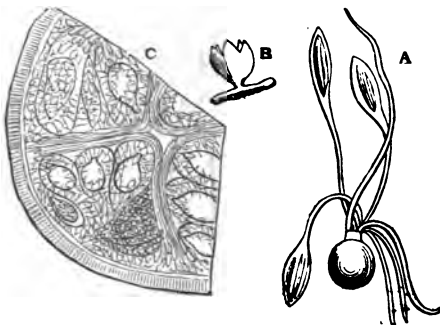


Fig. 285.

Fig. 284.—The *Lycopodium Aphodium*, or Club Moss.

Fig. 285.—A, full-grown plant of *Marsilea pubescens*; B, spore (opened), natural size; and C, section of spore magnified, with the contained spores. Both of the *Olinaria globulifera*.

capsules, or sporocarpia, and, as a rule, are filled with sporules (or pollen) in the form of powder like grannies, when they are called *antheridia*; or they contain several rounded fleshy bodies analogous to buds, much larger than sporules, and named *Oophoridia*. In *Marsilea* the organ of fructification is a modified leaf, and consists of two valves. The fructification is immediately placed upon a number of spikes, covered by ovules and anthers, attached at first to the modified leaf by a mucilaginous ring. The Split Mosses and the Urn Mosses have organs of fructification placed at the summit of their branches. These are called *Antheridia*, and have an elongated flattened form; and, on being ruptured, emit a multitude of spiral threads, with an enlarged extremity, sometimes curled, and at others straight in their figure.

These are said to be abortive Antheridia by certain writers; but there is no doubt, from their configuration and rapid motion, that they are true Phytozoa, or organs of reproduction.

This organ in the Urn Mosses, as the *Funaria hygrometrica* (Fig. 288), is somewhat more

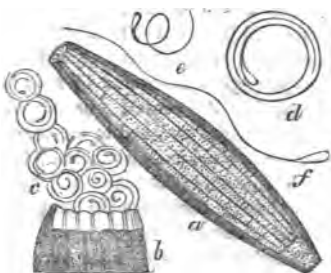


Fig. 286.—The Antheridium (a) of the *Polytrichum Commune*, emitting at b a number of elongated fibres, c d, with an enlarged free end, e f.

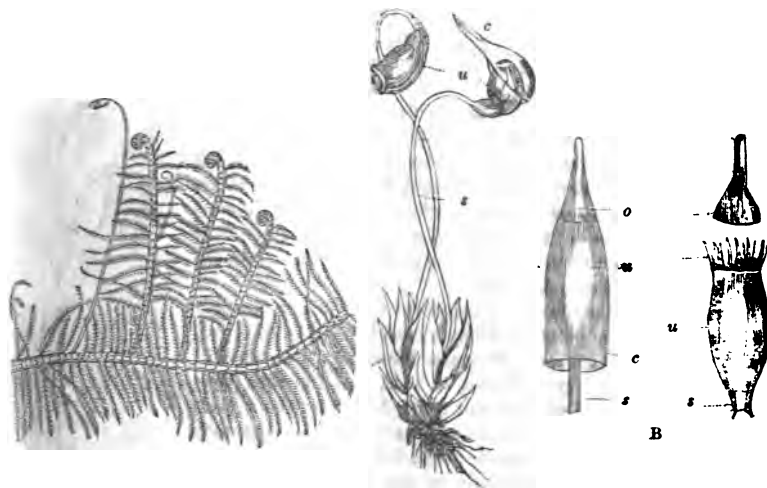


Fig. 287.

A

Fig. 288.

Fig. 287.—The *Hypnum Castrensis*, or Feather Moss, with its organ of fructification, situate at the top of a long seta or stalk, A.

Fig. 288.—A. The urns (u) of the *Funaria Hygrometrica*, supported on setae (s), and covered by calyptra (c). B. s, the seta; c, the calyptra; u, the urn; and o, the operculum of the encalyptra.

complicated, and possesses parts which are most sensitive to the presence of moisture; so much so, that the observer breathing upon them causes them at once to contract. It is

known as the *sporangium* or *theca*, and its contents are called *sporules*; but besides these, there are several bodies called *prospophyses*, enveloped in a membrane which subsequently bursts, and is curved to form the *calyptra*. The *calyptra* is termed *dimidiata* when the sporangium bursts on its side, and *mitriform* when the membrane is detached at its base. The sporangium is covered by a lid or *operculum*, and incloses a multitude of sporules surrounding the central axis, or *columnella*, and oftentimes inclosed in several cells, with their septa attached to the columnella. The whole rests upon an elevated stalk, or *seta*. It is lined and also inclosed by two membranes—the inner and outer *peristomia*—which have a toothed edge; and by closing the orifice, especially when moistened, as by the breath, constitute the tympanum. It is bounded above by an elastic external ring, or *annulus*.

Whether any, and what part of the above organs can be appropriated to the sexes, is a subject of much dispute; but it is highly probable that the sporules are the analogues of the pollen in flowering plants, and it has been ascertained that they emit tubes very similar to pollen tubes.

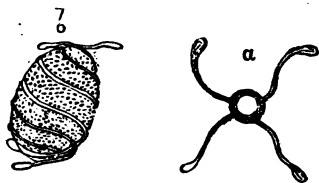


Fig. 289.—a, four elaters attached to and surrounding a spore, b.

There is an arrangement of the internal parts of the organs of fructification in the Horse-tails which greatly resembles that described in the Lycopodium—viz., a spiral fibre moving with great rapidity, and influenced, as in the Funaria, by moisture. There are usually two or more such fibres having an enlargement at their free ends, and connected to a central organ, around which they wrap themselves spirally (Fig. 289). On the application of moisture they instantly wrap themselves around the spore, b, but on its withdrawal they relax their hold, a. These structures are contained within cases or sporangia, which are arranged around the apex of the stem in the form of a cone (Fig. 290). It is probable that the elaters represent the male, and the spores the female parts of the sexual organs.

In Liverworts, as *Marchantia polymorpha*, the foliaceous organ is termed *thallus* or *frond* indifferently, and is a flat lobed organ, lying flat upon the ground. Its reproductive organs are three in number:—1st., little green bodies, or buds, placed in cups (Cystulae) on the upper surface of the frond, believed to be a viviparous apparatus; 2nd., sporangia, or female parts, placed beneath calyptra, or a stalked receptacle; and 3rd., oblong bodies, or anthers, found in other sporangia on the upper surface of the frond. These last resemble the spiral fibres of the *Chara vulgaris* (Fig. 291).

The Scale Mosses (*Jungermannia*) have a *pericladium* arising amongst the leaves, from which a seta proceeds, and bears a valvular brown case, or *sporangium*, containing a number of spiral fibres (Fig. 295), which are highly *hygonetric*, and are intermixed with sporules, or female organs. There is also a calyptra or the ruptured membranous bag (*Epigonium*).

There is an arrangement of the internal parts of the organs of fructification in the Horse-tails which greatly resembles that described in the Lycopodium—viz., a spiral fibre moving with great rapidity, and influenced, as in the Funaria, by moisture. There are usually two or more such fibres having an enlargement at their free ends, and connected to a central organ, around which they wrap themselves spirally (Fig. 289). On the application of moisture they instantly wrap themselves around the spore, b, but on its withdrawal they relax their hold, a. These structures are contained within cases or sporangia, which are arranged around the apex of the stem in the form of a cone (Fig. 290). It is probable that the elaters represent the male, and the spores the female parts of the sexual organs.



Fig. 290.—The Equisetum, or Horse-tail, with fructification.

None of the members of the various kinds of Mosses now described have any vascu-

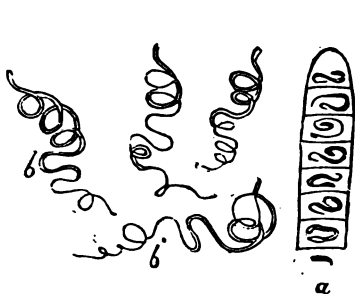


Fig. 291.



Fig. 292.

Fig. 291.—a, Phytozoa, or male parts, *in situ* within the cells; b, the same, detached from the cell-wall in the chara.

Fig. 292.—*Marchantia Polymorpha*, or Liverwort, with its broad frond, A, and organs of fructification, B.

lar tissue, but are wholly composed of cellular tissue of various forms.

Lichens.—This important class of plants are more particularly found in regions so far north that more highly and more delicately formed plants cannot exist; as in the instance of the Iceland Moss (*Cetraria Islandica*), so useful to the reindeer in its native regions, and employed as a medicinal agent in this country. It consists of a lobed leaf, called *frond*, *thallus*, or *blatemas*, of various forms and degrees of consistence, and which



Fig. 293.

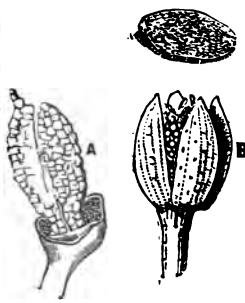


Fig. 294.

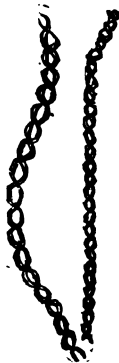


Fig. 295.



Fig. 296.

Fig. 293.—Lichen growing upon a piece of rotten wood.

Fig. 294.—The fructification of the *Jungermannia*. A, very young spore-case still covered by the calyptra; B, the same, quite developed, with the hyalina ripe and bursting, and presenting to view the inclosed spores.

Fig. 295.—Spiral fibres or elaters of the *Jungermannia* (Scale Moss.)

Fig. 296.—*Acrostalagmus Cinnabarinus*, very highly magnified, with the fructification at the end of the filaments.

differs from the like organ in all higher members of the vegetable kingdom, in the fact that not merely a part but the whole of its intra-cuticular substance is devoted to

the functions of reproduction. The upper cuticle is pierced by two forms of fructifying organs—viz., *soredia*, or masses of powdery bodies, scattered over the surface; and



Fig. 296.*



Fig. 297.

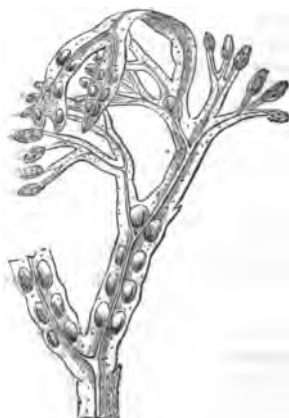


Fig. 298.



Fig. 299.

- Fig. 296.*—Section of the shield in a *Parmelia*, showing the position of the spores.
 Fig. 297.—Magnified representation of the cellular structures of Sea-weeds. (Algae.)
 Fig. 298.—The *Fucus Vesiculosus*, or Bladder-wrack.
 Fig. 299.—*Promelia Perforata*:—Lichen, with projecting shields.

shields (Scutella, Fig. 299, A), surrounded by a rim, and containing wool, or tubes filled with spores.

Fungi, or Mushrooms.—This is a most extensive family of plants, and assumes forms infinitely more diverse than is represented by the members to which the name is

popularly applied. The most common, and at the same time the least noticeable, forms are the minute substances which appear in and upon decomposing fluids, and as vegetable parasites upon many living plants and animals (Fig. 300). All alike, however, consist exclusively of cellular tissue, but differ greatly in its arrangement, and especially in the nature of their reproductive organs. In the minute bodies just

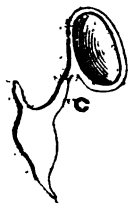


Fig. 300.

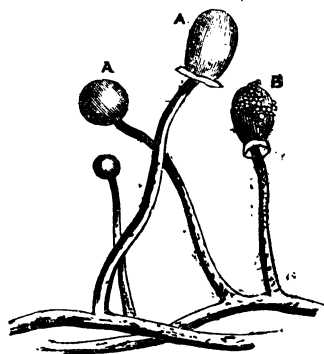


Fig. 301.

Fig. 300.—The conformation of the common Mushroom (*Agaricus campestris*). A. a, the pileus; b, the lamella, covered by the hymenium; c, the stipe; d, the mycelium. B. a portion of the hymenium, with basidia in four different stages of formation. C. a perfectly developed spore in one of the processes of the upper part of a basidium.

Fig. 301.—*Mucor Mucedo*, showing the asci, A, and the sporidia, B.

mentioned, the organ of fructification is simply one enlarged cell, containing the sporules or spores; but in the common Mushroom there are true sporidia contained in asci or sporule cases, and in a few there are moveable spiral fibres or elaters. The former division of fungi is the most interesting and accessible; so that we would urge our readers, possessed of some microscopic knowledge, to examine the various forms of mould so universally distributed. No preparation or subdivision of the substance is necessary, except that of placing a very small portion of it in a little water.

Algæ, or Seaweeds.—This is the last one of the Fungi, the lowest forms of vegetable life and growth, and is the boundary line of, or rather the neutral territory between, the animal and vegetable kingdoms. The members of this class are universally distributed, and are all different, from the string of cells found in a drop of stagnant water to the beautifully varied and large sea-weeds familiar to many of our readers (Fig. 297). It is a class, however, which is best represented in the southern or tropical seas; for there, not only is there greater variety of appearance, but the masses in which they abound almost exceed belief. Moreover, in such, as also in many representations on our own shore, it seems almost impossible to deny the animal characters with which many observers have invested them. Nothing can so much relieve the monotony of a sea-side residence as to fix a microscope on the sands, and examine these beautiful objects, fresh from the salt water.

As in other families, the reproductive parts, for the most part, are called spores, and are found in the ordinary cells of the plant, as in Fig. 297, or are gathered together into sporangia, or spore-cases, of various kinds. We cannot enter into the dispute as to the sexuality of these as of other members of the class of flowerless plants, but

would remark that a kind of conjugation has been noticed in the Confervæ, or lowest members of the class (Fig. 302), from which the spores are believed to result. These spores are endowed with the faculty of motion within the cell, and more particularly soon after their extrusion, as mentioned at page 4, Fig. 2.

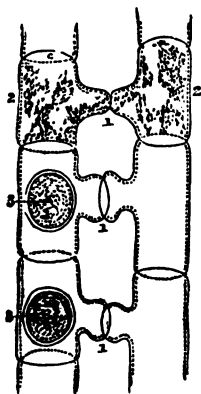


Fig. 302.—Confervæ, with spores lying within cells, which have undergone the process of conjugation, at 1.

In closing this account of the structure in flowerless plants, we would remark that a great multitude of terms have been invented to describe certain minute peculiarities in reference to the seeds or sporules, and the cases or ovaries in which they were developed; but as they would occupy much space, and be tedious to readers of all classes, we omit further mention of them. In reference to the sexual organs of the whole class, it must still be admitted that the whole question is *sub judice*, and that we can only affirm that, whilst such plants reproduce themselves with the most astonishing rapidity (a rapidity which seems to be in the inverse ratio of their organization), distinct sexes either do not exist, or are possessed of forms as yet unrecognised. Lastly, cellular tissue, and that alone, is the form of organization of all except the highest divisions; but the cells are very varied in figure, size, and arrangement, and are commonly coloured green or red, as in the Confervæ and Sea-weeds; or are resplendently coloured, as in many Fungi. They are not the less beautiful and interesting because their structure has a simple

basis; but, on the contrary, evidence, in a remarkable degree, the power and wisdom of the Creator in the infinitely varied and beautiful arrangements of so simple an object.



SYSTEMATIC BOTANY, OR THE CLASSIFICATION OF PLANTS.

HAVING, in the preceding pages, described all the parts and organs which enter into the composition of individual plants, we are prepared to take a wider view, and determine the mode by which masses of plants may be grouped together. This is termed Classification.

This department of botanical science is vastly more extensive than that which treats of the structure of plants; so that it is not possible, in a treatise like the present, to consider the subject in any lengthened detail. We therefore purpose, after offering some introductory remarks, to consider the Linnæan and the natural systems of classification, and to name the most common or important plants which have been arranged under each head.

The necessity for a classification of plants must have been felt at all periods, even in the Grecian and Roman eras, when the total number of known species did not exceed 1,000; but since, at the present day, upwards of 100,000 species have been named and described, the necessity has become absolute. The only question on which botanists have been at issue refers to the principles on which that classification should be founded. In the first place it is imperative that each plant should have a distinctive appellation, or any description of it would be in vain. Then, again, since 100,000 distinct names, assuming for a moment that so many could have been invented, could not have been borne in mind by any person, the next step in the process would be to ascertain if any of this number could be grouped together under one name, but yet having a special term to indicate its individuality.

The success of this inquiry would, of course, depend upon the existence or otherwise of any anatomical characters which would at a glance be found common to both. Such resemblances were soon discovered; and the term *Rose*, for instance, was found to suffice for very many species, with the addition of white, red, &c., to mark their individuality. Thus the term *Rose* denoted a *genus*, and *white* the *species*; and in this mode the number was reduced within reasonable proportions.

But this first was not the last step, for it was ascertained that on some one point, or on many points, the genera resembled each other; and thus the term *Icosandria*, for example, was devised, which should comprehend the *Rose*, and the *Apple*, and the *Strawberry*, and others having these characters in common. This then gave rise to a system of classes and orders, the term *Icosandria* representing one of the classes. The orders were subdivisions of the classes, and referred to certain minutæ in which all the members of the orders did not agree. Thus the nameless plant became at length the *Rosa Alba*, of the class *Icosandria*, and order *Polygamia*.

This is precisely the plan adopted in the classification of animals. Thus the *Cow* is the *Bos taurus* of the class *Mammalia* and order *Ruminantia*. It is not, however, a perfect plan; and as the number of objects to be included have continually increased, it has been found necessary to invent a more general term—as that of *family*—which shall comprehend a number of classes. Reversing, then, the order of classification which has already been given, we may first refer a plant to a *family*; next to a *class* and *order*; and then find its *generic* and *specific* names.

The term *variety* has also been introduced to indicate the existence of some trifling change in a *species*; and although the boundary between a *species* and a *variety* is not capable of nice definition, yet it may be stated that a *variety* does not so reproduce

itself by seed as that its own form shall result, but so that a return to its original species shall inevitably follow. There are also *Hybrids* in plants as in animals, and resulting from the operation of the same law—*viz.*, the admixture of the sexes, not of the same, but of different species of one genus.

The first point will probably depend upon one or two features only; but the last will require a knowledge of every part of the plant. Thus, whilst the multitude of names which have no necessary significance tends to confuse and weary the mind, the various steps of that classification render the task the lighter, and indeed infuse a deep interest into the study. It is a mark of unbounded knowledge, on the part of the Creator, to have made so great a multitude of varied objects; but it is not the less so that He has made many of them on a common plan, and has given to us the capability of unfolding His designs. It is no mark of our mental capability to have found or seen a plant; but it is not a little flattering to us to have discovered or perceived the principle on which the plant was constructed; and this is the central point of interest to the philosopher.

But the school-boy is not without his gratification. To point out the flower, the name of which we know, and to gather that to-day which long ago we first discovered, and *discovered* in the company of some one whose society we cherished, may yield pleasure to any one. Thus we would offer encouragement to the young botanist, by the assurance that the road is not so hilly as it appears to be, and that it is rendered shorter by the snatches of pleasure which fall to the lot of the anxious traveller.

There have been, and still are, various modes of classification; and since all depend upon the selection of certain parts of plants as their basis, it cannot surprise us that they should be held in various degrees of estimation.

A prime consideration, in the selection of distinguishing characters, is, that those characters shall be constant, and not greatly influenced by accidental circumstances. Such a condition, if it exist at all, can only belong to those parts which are essential to plants. These essential parts are connected with the function of reproduction, and have been referred to in every system of classification; but as nature does not slavishly follow the path which she herself has marked out, we meet with occasional variety even here. The flower would naturally attract attention; and in the earlier attempts at classification, its permanent parts, the stamen and pistils, were exclusively selected. This was called the *sexual system*; and was first pointed out by our renowned countryman, Grew, in the seventeenth century, and a century later was perfected by Linnæus.

This one prime principle of *constancy*, then, was that upon which the Linnæan system was founded, and to which it still owes its continued existence. The system is, moreover, very simple in its arrangement, and therefore has been at all times in favour with beginners, and with all those who have not cared to drink deeply of the Pierian spring; and, in spite of its insufficiency, it will doubtless be handed down to succeeding generations.

A perfect classification, however, demands more than mere constancy; and it is in these further requirements that the Linnæan system has been found wanting. It is necessary that no violence be offered to that uniformity of organization which is well known to exist in the vegetable kingdom, so that plants evidently widely dissimilar shall not be grouped together. Again, since all plants have qualities which are beneficial or prejudicial to the health of man or animals, and since these qualities are known to be associated with certain similarities of organization, it is demanded that plants of greatly dissimilar properties shall not be classified together. These two last require-

ments clearly call for a more extensive knowledge of the anatomy of plants than that upon which the sexual system was founded, and should more nearly approach to a natural association of these products of creation. Systems have been founded which are intended to answer to all the three above-mentioned requirements, and have been termed *natural system*, in opposition to that of Linnæus, which, from its narrow basis, was known as the *artificial system*. It is evident, however, that the natural systems are the more desirable, and they are rapidly superseding the Linnæan arrangement; but as we are addressing ourselves to an extended circle of readers, we deem it a duty, first, to make them acquainted with the latter, and then to give them an insight into the former.

LINNÆAN SYSTEM.

The Linnæan system is based upon the existence of sexual organs, and is varied according to the number and position of each division of these organs. It consists of *classes* and *orders*; the former associated chiefly with the stamens, and the latter with the pistils.

There are 24 classes, of which 23 belong to flowering and one to flowerless plants. A reference to the annexed plan will show that the first eleven classes are named according to the number of the stamens—*viz.*, from 1 to 12 stamens; the last, however, admitting also of more than 12 stamens. The 12th and 13th classes have an indefinite number of stamens; but in the former (*Icosandria*) they are all attached to the calyx, whilst in the latter they remain free from their origin in the receptacle. This difference appears to be a trifling one, but it is constant, and in practice, moreover, is well defined. The 14th and 15th classes depend upon the number and relative length of the stamens, there being two long and two short stamens in the former, *Didynamia*, and four long and two short ones in the latter, *Tetradynamia*. In the 16th, 17th, and 18th classes, the stamens are associated into bundles; one bundle in *Monodelphia*, two in *Diadelphia*, and three or more in *Polydelphia*. In the 19th class the stamens are also united into one bundle, *Syngenesia*; but they thus form a tube through which the pistil passes. The class termed *Gynandria*, indicates that the stamen and pistils are united together. The 21st, 22d, and 23d classes, comprehend plants in which the male and female parts are not met with together in the same flower. Thus in *Monœcia* separate male and female flowers are found on the same plant, whilst in *Diœcia* one plant is entirely male and another exclusively female; and in *Polygamia* both bi-sexual and uni-sexual flowers grow on the same tree. The 24th and last class embraces an heterogeneous assemblage of low organized plants, having this one property in common, that their sexual organs are concealed, whence the term *Cryptogamia*.

The foregoing 24 classes are divided into numerous orders. The orders of the first 13 classes are based upon the number of the pistils, which vary from one, *Monogynia*, to twelve, *Dodecagynia*, and more than twelve, *Polygynia*; whilst the 16th, 17th, 18th, 20th, 21st, and 22d classes are subdivided into orders according to the number of their stamens. The nature of the ovary determines the orders in the 14th and 15th classes. The 23d class, or that termed *Polygamia*, has but one order, and that depends upon the fact that certain of the flowers on the same plant are bi-sexual, whilst others are uni-sexual. The 19th class, or *Syngenesia*, has orders depending upon the forms and fertility of the florets; and the last one, *Cryptogamia*, is subdivided according to the families of which it is composed.

The following tables contain a complete summary of the Linnæan plan of classification. The reader will understand that the table reads across the two pages.

COMPLETE SCHEME OF THE LINNÆAN CLASSIFICATION.

NAMES.	CLASSES.	DESCRIPTIONS.
1. Mon-andria (μονος, one; ανδρος, male)	1 Stamen.	
2. Di-andria (δύς, two)	2 Stamens.	
3. Tri-andria	3 do.	
4. Tetra-andria	4 do.	
5. Pent-andria	5 do.	
6. Hex-andria	6 do.	
7. Hept-andria	7 do.	
8. Oct-andria	8 do.	
9. Enne-andria	9 do.	
10. De-candria	10 do.	
11. Dode-candria	12 or more Stamens.	
12. Icos-andria	20 do.	attached to Calyx
13. Poly-andria (πάλυς, many)	20 do.	do. Receptacle
14. Didy-namia	4 do.	2 long, 2 short
15. Tetra-dynamia	6 do.	4 do. 2 do.
16. Mono-delphia (μονος, one; δελφος, brother-hood)	Filaments united into 1 set	
17. Dia-delphia (δύς, two)	do. do. 2 sets	
18. Poly-delphia	do. do. 3 or more sets	
19. Syn-genesia (σύν, together; γένεσις, birth)	Anthers united	
20. Gy-nandria (γυνή, woman)	Stamens attached to the Pistil	
21. Mon-œcia (οικος, house)	Flowers with Males only; others with Females only on the same tree	
22. Di-œcia	Flowers with Males only; others with Females on different trees	
23. Poly-gamia (γάμος, marriage)	Unisexual and bisexual flowers on same and on different trees	
24. Cryptogamia (κρυπτω, to conceal)	The flowers not evident	

The simplicity of the system will be better observed on reference to the following plan, adopted from the "*Encyclopédie des Connaissances utiles*:"—

TABULAR VIEW OF THE CLASSES OF THE LINNÆAN SEXUAL SYSTEM.

				CLASSES.
Plants with	Sexual organs apparent.	Flowers hermaphrodite.	Stamens distinct from pistils.	1. Monandria.
				2. Diandria.
	Free.	Size undetermined.	Number of stamens.	3. Triandria.
				4. Tetrandria.
Sexual organs hidden.	United.	Stamens placed upon the pistils.	Number and insertion.	5. Pentandria.
				6. Hexandria.
				7. Heptandria.
				8. Octandria.
				9. Enneandria.
	Flowers of one sex only.	Size undetermined.	Proportionate size.	10. Decandria.
				11. Dodecandria.
				12. Icosandria.
				13. Polyandria.
				14. Didynamia.
	By their filaments.	By their anthers.	By their filaments.	15. Tetradynamia.
				16. Monadelphina.
				17. Diadelphia.
				18. Polyadelphia.
				19. Syngenesia.
				20. Gynandria.
				21. Monœcia.
				22. Diœcia.
				23. Polygamia.
				24. Cryptogamia.

As we propose to give, in very brief detail, both the Linnæan and the Natural systems, and shall therefore have to travel twice over the same ground, it will be more

COMPLETE SCHEME OF THE LINNÆAN CLASSIFICATION.

NAMES.		ORDERS.	DESCRIPTIONS.
Monogynia	Digynia (γυνή, a woman)	.	1 and 2 Pistils.
Do.	do. Trigynia	.	1, 2, 3 do.
Do.	do. do.	.	.
Do.	do. Tetragynia	.	1, 2, 4 do.
Mono, Di, Tri, Tetra, Penta, and Polygynia	do.	.	1, 2, 3, 4, 5, and many Pistils.
Do. do. do. do.	do.	.	1, 2, 3 do.
Do. do. do. do.	Heptagynia	.	1, 2, 4, and 7 do.
Do. do. do. do.	.	.	1, 2, 3, 4 do.
Do. do. do. do.	Hexagynia	.	1, 3, 6, do.
Do. do. do. do.	do. Decagynia	.	1, 2, 3, 5, and 10 do.
Do. do. do. do.	do. Dodecagynia	.	1, 2, 3, 4, 5, 6, and 12 do.
Do. do. do. do.	Polygynia	.	1, 2, 5 do.
Do. do. do. do.	do.	.	1, 2, 3, 4, 5 do.
Gymnospermia (γυμνός, naked; σπέρμα, seed)	.	.	Naked seeds.
Angiospermia (αγγός, a vessel)	.	.	Seeds inclosed in a vessel.
Siliculosæ, small pod; Siliquosæ, large pod.	.	.	.
Triandria, Pent., Hex., Hept., Oct., Dec., Dodec., and Polyandria.	.	.	.
Do. do. do. do.	Do.	do.	.
Polygamia æqualis, Superflua, Necessaria, Segregata.	.	.	.
Monandria, Diandria, Hexandria.	.	.	.
Monandria, Di., Tri., Tetra., Pent., Hex., Oct., Icos., Poly., and Monodelphia.	.	.	.
Monandria, Tri., Tetra., Pent., Hex., Oct., Enne., Dec., Dodec., Icos., Poly., Monodelphia.	.	.	.
Monœcia, Dioœcia.	.	.	.
Filicels, Lycopods, Muscals, Liehenals, Fungals, Algals.	.	.	.

convenient to our readers, if we illustrate the Linnæan system from the English flora exclusively, and the Natural system from the foreign plants.

CLASS I.—MONANDRIA.

This is distinguished by having but one stamen, and is subdivided into two orders, *Monogynia* (one pistil), and *Digynia* (two pistils). It contains but few English plants—viz., five genera and fourteen species—and these remarkable neither for beauty nor utility. Four genera—viz., *Salicornia*, *Hippuris* or *Mare's-tail* (growing in ditches), *Zostera*, and *Chara*, commonly known as *Stonewort* or *Water Horse-tail*—have but one pistil; whilst the *Callitriche*, or *Starwort*, is the only genus having two pistils. The *Chara* offers the most numerous species (six), and is, perhaps, the least uninteresting of all the genera. It is found in ditches both of fresh and salt water. The organization of members of this class is

of a low grade.



Fig. 303.
Monandria
Monogynia.



Fig. 304.
Monandria
Digynia.

CLASS II.—DIANDRIA.

This class has two stamens and two orders—viz., *Monogynia* and *Digynia*. It contains several plants of interest in the eleven genera, and thirty-nine species of which it is composed. Under the order *Monogynia* we find the well-known *Privet* (*Ligustrum*); the *Fraxinus*, or common *Ashtree*; the prolific, and almost ubiquitous weed *Veronica*, with its nineteen species; the *Pinguicula*, found in bogs; *Utricularia*;

Lycopus, or Cat-mint; *Salvia*, or Sage; *Circæa*, or the Enchanter's Night-shade, found in country parks and under field-hedges; the *Lemna* or Duckweed, covering every stagnant pool; and the *Cladium*. The first eight genera have inferior monopetalous flowers, whilst the *Circæa* has a superior flower, and the two last are destitute of flowers.

The most agreeable member of this class is the *Anthranthum odoratum*, a sweet scented meadow-grass, which possesses two pistils; and, as it has but two stamens, is cut off from the great family of grasses, to which it clearly belongs.

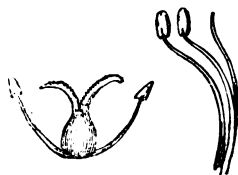


Fig. 305.
Diandria Digynia. Diandria Monogynia.

CLASS III.—TRIANDRIA.

This is a most extensive and invaluable class of plants, comprising all our British grasses except one, including the various cereals, as wheat and oats, so necessary to man. The members of this class are the means of sustaining the life of man, and of almost all animals, and are the most widely distributed, and the most abundant of all plants.

There are forty-eight genera, and one hundred and sixty-five species, arranged in three orders, *Monogynia*, *Digynia*, and *Trigynia*.

The order *Monogynia* contains twelve genera, of which five have superior flowers, and contain medicinal or poisonous plants, as the *Valeriana*, *Crocus*, and *Iris*. Six others have superior flowers, and comprehend many of the common rushes; and one is a true grass, the *Nardus stricta*. The order *Digynia* is remarkable for its natural assemblage of grasses; twenty-eight of which have chaffy flowers in panicles, arranged in bracts containing one, two, or three flowers. Five others—amongst which are the *Wheat*, (*Triticum*), and *Barley* (*Hordeum*)—have a spiked inflorescence. Of all these genera, only one is known to possess poisonous properties—*vis.*, the *Lolium temulentum*, or Bearded Darnel. The *Festuca ovina* and *Duriuscula* are the most common grasses.



Fig. 306.
Triandria Digynia. Triandria Monogynia.



Fig. 307.
Triandria Trigynia.

This is a class of plants offering great difficulty to the young botanist, on account of the apparent resemblance of many genera, and the absence of the calyx and corolla of other plants. But this difficulty is not unconquerable; and when it has been surmounted the pleasure attending the acquired knowledge is very great. The characters of this inflorescence have been discussed at pages 108 and 109.

The third order, *Trigynia*, has nothing in common with the last order unless we except the number of stamens, and this tends to show the great defect in the Linnæan system. It contains

but three genera—*Montia*, *Polycarpon*, and *Holosteum*.

CLASS IV.—TETRANDRIA.

The flowers in this class have four stamens, and one, two, or four pistils—*Monogynia*, *Digynia*, and *Tetragynia*. It is not an extensive class, having only twenty-two genera and sixty-five species; and of these the large majority are valueless weeds.

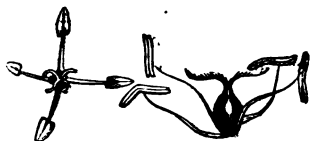


Fig. 308.

Tetrandria Tetragynia. Tetrandria Digynia.



Fig. 309.

Tetrandria Monogynia.

The order *Monogynia* is the largest, and contains fifteen genera, four of which have no petals—*vis.*, *Alchemilla*, or *Lady's-mantle*; *Sanguisorba*, *Isnarda*, and *Parietaria*; whilst nine are monopetalous, and two are polypetalous, with four petals. There are seven genera, possessing four pistils, and amongst them the *Holly*, *Ilex*, *Lime-tree*, *Tilia*, and *Pond-weed Potamogeton*. A few plants are supposed to possess medicinal properties, as the *Rubia*, or *Madder*; *Galium*, or *Bed-straw*; and *Sanguisorba officinalis*, or *Great Burnet*. The *Dipsacus Fullonum*, or *Fuller's teal*, the hairs of which (Fig. 113) are so useful to clothworkers, belongs to this class. Several other members possess a certain degree of beauty—as the *Scabiosa* and the *Ilex*, which is the cheering emblem in our Christmas festivities. The most numerous plants, under this head, are the *Plantago*, or *Plantain*, with its spike of sessile flowers, the *Alchemilla*, and the *Potamogeton*.

CLASS V.—PENTANDRIA.

This is a most important, numerous, and varied class of plants, and has ninety-four genera and two hundred and ten species. The plants have five stamens, and one, two, three, four, five, six, or an indefinite number of pistils (*Polygynia*). It is not possible to give any one expression which shall represent this class as a whole; but there are many of its members which may be arranged together both in structure and properties; so that the class is a compound of several bodies or classes of plants.

The order *Monogynia* is very extensive, comprehending no fewer than forty genera. Thirty-one of these have monopetalous corollas; six are polypetalous of five petals, and three are apetalous. Ten genera are closely associated together, as shown by having inferior monopetalous flowers with two or four naked (so-called) seeds, and a covering of rough hairs over the plant. Such are *Symphytum* or *Comfrey*, *Echium*, *Borago*, *Anchusa*, or *Alkanet-root*, *Cynoglossum*, and the sentimental *Myosotis* or *Forget-me-not*. This is a compact and well-defined body of plants. Fifteen other genera are distinguished from the above, by having the seeds more manifestly inclosed in a seed vessel; and amongst these are the beautiful *Primula* or *Primrose*, and *Cowslip*, *Mertyanthes* or *Bog-bean*, *Anagallis*, *Convolvulus*, *Polemonium*, or *Jacob's-ladder*, *Vinca*, or *Reriwinkle*, and *Verbascum*; as also the poisonous *Atropa*, *Belladonna*, or *Deadly Night-shade*, the *Hyoscyamus* and the *Solanum*; *Tuberosum*, with its poisonous berries and edible subterranean stem, known as the *Potato*.



Fig. 310.

Pentandria Monogynia.

The six genera, with superior monopetalous flowers, are of mixed characters, and

three of them are well known—*viz.*, the *Lonicera* or Honeysuckle, *Campanula* or Bell-flower, and *Lobelia*.

Of the six genera with polypetalous flowers, four have them inferior, as the *Viola* or Violet, and *Rhamnus* or Buckthorn; whilst two are superior—*viz.*, the delicious *Ribes* or Currants and Gooseberries, and the *Hedera Helix* or common Ivy.

The order *Digynia* is also very extensive and important, since there are thirty-six genera belonging to it, many of which possess valuable medicinal properties. Two of these are monopetalous—*viz.*, the *Gentiana* and the *Cuscuta*; and four apetalous, the *Beta maritima*, *Chenopodium*, *Salsola*, *Ulmus* or Elm-tree, and *Herniaria*. The



Fig. 311.
Pentandria Digynia.



Fig. 312.
Pentandria Trigynia.



Fig. 313.
The *Drosera*, or Sundew.

greater number are, however, distinguished by the umbelliferous mode of inflorescence, and constitute a naturally associated division. All have five superior petals and two seeds, but differ amongst themselves as to the presence and arrangement of bracts. Amongst this numerous and highly-important class of plants we may mention the *Carum carui* or Caraway seed, *Meum Fœniculum* or Fennel—with its aromatic oil contained in the vittæ of the seeds, the *Daucus Carota* or Carrot, *Heracleum* or Cow-parsnep, *Pastinaca Sativa* or common Parsnep, *Bunium Flexiosum* or Earth-nut, sought after by boys and animals, and the *Apium graveolens* or Wild-celery; the stately *Angelica*, the poisonous *Conium Maculatum* or Hemlock, *Cicuta Vireosa* or Water Hemlock, *Sium* or Water Parsnep, the bitter *Gentiana*, and the *Hydrocotyle* with

its peltate leaf. The various genera of Parsley and Parsnep exceed any other in number; and nearly the whole of this large subdivision may be naturally arranged together.

In the order *Trigynia* are two genera with superior flowers, which are well known: the *Sambucus Niger*, or Elder, with the inflorescence called a cyme, and the elegant *Viburnum* or *Lilac*; and also three others of less notoriety, which have inferior flowers.

The orders *Tetragynia* and *Hexagynia* have each one genus known well to botanists, and growing on boggy ground—*viz.*, *Parnassia* in the former, and *Drosera* or *Sundew* in the latter. The *Drosera* is remarkable as being the only English plant which exhibits sensibility to touch in a marked degree. It possesses a number of remarkable glands upon the surface of its leaves (page 70), which emit a tenaceous fluid by which flies are caught, and which are subsequently appropriated as food for the plant.



Fig. 314.

Pentandria
Pentagynia.

Pentandria
Tetragynia.

pritated as food for the plant.

The order *Pentagynia* possesses three genera, two of which are of interest—*viz.*, the *Statice* or *Thrift*, with its cheerful head of flowers, and the *Linum* or *Flax* plant.

The last order, *Polygynia*, includes but one genus, and that of but little value—the *Myosurus* or *Mouse-tail*.

Our readers will now perceive how remarkable is the combination of plants brought together by this class of the Linnæan arrangement, and how unfitting it is that so many varied alliances should be enrolled under one head. It is also well to remember that three well defined natural classes may be formed out of many of its members,—the one with the umbelliferous inflorescence (*Umbelliferae*), another with a rough hairy cuticle (*Boraginaceae*), and a third with highly poisonous properties and sombre aspect (*Solanaceae*). It is a class remarkable both for the beauty and utility of its members—a utility embracing both medicinal and dietetic qualities.

CLASS VI.—HEXANDRIA.

This class is characterized by having six stamens, and is divided into four orders—*viz.*, *Monogynia*, *Digynia*, *Irigynia*, and *Polygynia*; and contains twenty-six genera and eighty-five species.

It is remarkable as a class of flowering plants for the endogenous structure of its members, as evinced by the straight veins of its leaves, and possesses many plants of great beauty and a few of considerable utility.

The order *Monogynia* comprehends nineteen genera, or two thirds of the whole class; and, with the exception of the *Berberis* or *Berberis*, with its compound leaves (page 101), sensitive stamens and fruit capable of being used as an excellent pickle; the *Peplis* and the *Frankenia*, and a few others, have a perianth (Fig. 201), as a covering of the flower, and a bulb for their underground stem. As examples of the class, we may mention the *Galanthus nivalis* or *Snowdrop*, or *Narcissus Ornithogalum* or *Star of Bethlehem*, *Hyacinthus*, *Scilla* or *Squill*, and *Tulipa*, all of which contain starch in their bulbs, and have beautiful flowers. The *Convallaria* or *Solomon's Seal* is an elegant member of this class. The *Asparagus officinalis*, and *Allium* or *Garlick*, are edible. The *Acorus Calamus* or *Sweet Flag*, emits an aromatic odour from its leaves and root, and is a grass not only used medicinally, but is much

employed in India as an artificial shade, when it is drawn into a frame, and water thrown upon and air driven through it so as to produce a low temperature and an aromatic odour.

The genera having the greatest number of species are the *Juncus* or Rush, and the *Luzula* or Wood-rush, under which terms are comprehended most of the Rushes growing in fresh and salt water in this country. They comprehend thirty-seven genera.

The orders Digynia and Polygynia have but one genus—*Oxyria* in the former, and *Alisma* *Plantago* or the Water Plantain in the latter. In the order Trigynia we find five genera, two of which are worthy of mention: the *Colchicum* *Aautumnale*, with



Fig. 315.
Hexandria Monogynia.



Fig. 316.
Hexandria Polygynia.



Fig. 317. Fig. 318.
Hexandria Trigynia. Hexandria Digynia.

its beautiful flower and medicinal cormus, and the common *Rumex* or Dock, and *Rumex* *Acetosa* and *Acetosella*, the common and the Sheep's Sorrel. The latter class of plants have no corolla.

Thus, whilst a few of the members of this class are worthless weeds, many others form the choicest parts of the collections of the horticulturists, and have obtained more attention in their cultivation and improvement than almost any other native plants. They comprehend nearly all our native flowering endogenous plants.

CLASS VII.—HEPTANDRIA.

This class possesses but one genus, the elegant European Chickweed *Winter-green*

Tristalis Europea, which has seven stamens, and one pistil. Its calyx, corolla, and

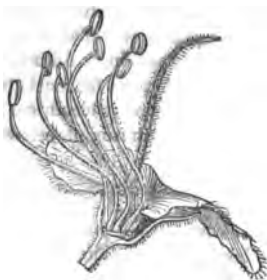


Fig. 320.
Heptandria Monogynia.

seed-vessel are each divided into seven parts, and well illustrate the law mentioned at page 111.

CLASS VIII.—OCTANDRIA.

The plants of this class have eight stamens, and are divided into four orders—*viz.*, *Monogynia*, *Digynia*, *Trigynia*, and *Tetragynia*. These are, however, few in number; forming only thirteen genera and forty species. The general characteristic of the class is rather that of beauty than of utility; and yet it is far from being wanting in either.



Fig. 321.
Octandria Trigynia.



Fig. 322.
Octandria Digynia.



Fig. 324.
Octandria Monogynia.



Fig. 323.
Octandria Tetragynia.

As instances of beauty, we may mention that in the first order there are the *Ænothera biennis*, or Evening Primrose; the *Epilobium*, or Willow-herb; and the gentle *Erica*, or Heath,—than which nothing can be more lovely in their separate characters.

Amongst the genera which may be termed useful, we instance the *Acer*, or Sycamore

and Maple; *Vaccinium Vitis-idaea*, or Cowberry; *Vaccinium oxycoccus*, or Cranberry; *Vaccinium myrtillus*, or Bilberry, with *Daphne Mezereum*, or Mezereum, and *Polygonum*, both of which possess valuable medicinal properties. The last-named plant belongs to the order *Trigynia*; and three others, *Adoxa*, *Paris*, and *Elatine* are ranged under the order *Tetragynia*. The *Epilobium* is the most abundant and fruitful in species, having nine, which inhabit either dry or moist localities. It is probable that the whole class must be regarded as possessed of irritating properties.

CLASS IX.—ENNEANDRIA.

This class, like *Heptandria*, contains but one genus and one species, the beautiful *Butomus Umbellata*, or flowering Rush, growing in ditches and the borders of stagnant waters. It has six pistils; and, consequently, the sole order in the class *Enneandria* is *Hexagynia*.



Fig. 325.—*Enneandria Hexagynia*.

CLASS X.—DECANDRIA.

This is a well-defined class of plants, the members of which are, for the most part, fitly associated together. They have ten stamens, and two, three, or five pistils, and consist of twenty-one genera and one hundred and seven species. A few are beautiful; but the majority are weeds, though not without a certain degree of interest, since they enliven by their small and modest flowers our mossy banks and waste places.

The order *Monogynia* has five genera, two with polypetalous flowers—*Monotropa*



Fig. 326.
Decandria Monogynia.



Fig. 327.
Decandria Digynia.



Fig. 328.
Decandria Pentagynia.



Fig. 329.
Decandria Trygynia.

and *Pyrola*, or Winter-green—and three with only one petal, as the *Arbutus* or Bearberry. There are five genera in the order *Digynia*—*viz.*, *Scleranthus*, *Chrysosplenium*, *Saxifraga* or *Saxifrage*, *Saponaria*, and *Dianthus* or *Pink*; whilst the order *Trigynia* has the *Arenaria* or Sandwort, *Stellaria* or Stitchwort, *Silene* or Catch-fly, and *Cherleria*—all weeds. The fourth order, or that called *Pentagynia*, has seven genera—the *Lychnis*; *Cerastium*, or Mouse-ear Chickweed; *Sedum*, or Stone-crop; *Cotyledon*; *Oxalis Acetosella*, or Wood-sorrel; *Agrostemma*; and *Spergula*. The *Dianthus*, *Saxifraga*, *Lychnis*, and *Oxalis* are doubtless the most beautiful; whilst the *Pyrola* and *Arbutus* exhibit certain feeble medicinal qualities. The class is somewhat remarkable for the number of species in proportion to that of the genera.

CLASS XI.—DODECANDRIA.

Hitherto the classes have succeeded each other by the addition of one stamen; but this addition is of two, there being no English plant with eleven stamens. The order contains but five genera and eight species (each plant having twelve stamens), subdivided into five classes—*vis.*, *Monogynia*, *Digynia*, *Trigynia*, *Tetragynia*, and *Dodecagynia* (twelve pistils). The genus and species *Sempervivum tectorum*, or House-

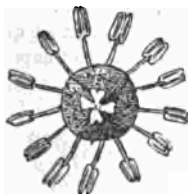


Fig. 330.

Dodecandria Tetragynia.



Fig. 331.

Dodecandria Trigynia.

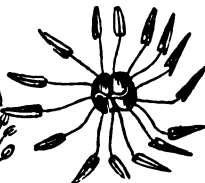


Fig. 332.

Dodecandria Digynia.

leek, is the best known, and belongs to the order Dodecagynia; after which may be placed the *Agrimonia Eupatoria* or *Agrimony* (*Digynia*), and then *Reseda* (*Trigynia*), and *Asarum* and *Lythrum* (*Monogynia*). The *Agrimonia* is presumed to possess alight



Fig. 333.—Dodecandria Monogynia.

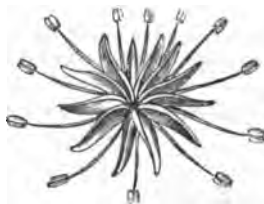


Fig. 334.—Dodecandria Polygynia.

medicinal properties; but the whole class is deficient, not only in number, but in beauty and utility.

CLASS XII.—ICOSANDRIA.

This is a most interesting class of plants, second, if at all, only to *Triandria*; and is one of those which chances to be well comprised in the Linnæan system. It contains twelve genera and sixty-seven species; and, with the exception of the *Pyrus Aucuparia*, or Mountain Ash, is either edible or harmless. It is distinguished less by the number than the position of the stamens—for there are an indefinite number of stamens; but they are attached to the calyx (*Epigynous*, Fig. 218; and so distinctive is that arrangement, that a member of the class is instantly recognized.



Fig. 335.—An Icosandrous flower.

It is divided into three orders—*Monogynia*, *Pentagynia*, and *Polygynia*. *Prunus*, or the Cherry and Black-thorn, is the only occupant of the first order; whilst three delicious plants—*Mespilus* or Hawthorn and Medlar, *Pyrus* (Pear, Apple, and Crab), and *Spiræa* or Meadow-sweet—have from two to five

stamens, and are arranged in the order Pentagynia. The third order has more than five pistils, and is termed indefinitely Polygynia; and in it are found the Rosa or Rose, Rubus or Bramble and Blackberry, Fragaria or Strawberry, Geum, Dryas, Tormentilla, Potentilla, and Comarum.

It is thus evident that this class comprehends nearly all our edible juicy fruits, besides the beautiful flowers which precede them, and such others as the Rose. It is a class of plants most readily diagnosed, in whatever part of the world they may be found, and, moreover, are, with few exceptions, healthful as food. A slight medicinal astringent influence is attributable to the Tannin, which is present in small quantities in such plants as the Potentilla, Tormentilla, and the Rose; and it is not improbable that,

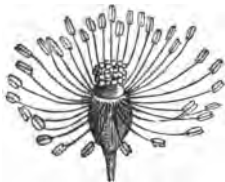


Fig. 336.
Icosandria Polygynia.



Fig. 337.
Icosandria Monogynia.

in a slight degree, it pervades the whole. This class of plants is, however, of greater use to the horticulturist than to the physician; for none are more susceptible of improvement from culture and admixture of species than the beautiful Rose (Fig. 207), the Strawberry, Apple, and other juicy fruits.

CLASS XIII.—POLYANDRIA.

This class differs, in a remarkable degree, from the preceding, especially in the powerful medicinal qualities with which its members are endowed. In this respect it resembles only a part of the heterogeneous class Pentandria, and with that division of plants furnishes many poisonous narcotic and narcotico-acrid substances. It has nearly double the number of genera, and yet fewer species than those possessed by Icosandria *viz.*, twenty-two genera, and fifty-five species. It is determined by the presence of numerous but an indefinite number of stamens, similar to the class Icosandria; but the two classes present some difference, the former having the stamens inserted beneath the ovary, and therefore hypogynous (Fig. 225), as in the Poppy. It is divided into three orders, named *Monogynia*, *Pentagynia*, and *Polygynia*.

The order Monogynia contains eight plants, of which four (*viz.*, the Papaver or Poppy, Chelidonium, Glaucium or Horned Poppy, and Actæa) have only four petals; whilst two (the Helianthemum) or Rock Rose, and Tilia Europæa (or the Lime Tree), have five; and two others, which are water plants (the Nymphaea Alba or the White Water Lily, and the Nuphar Lutea and Pumila or the Yellow Water Lily), have an indefinite number of petals. The above distinctions are, however, somewhat illusory; since no plants more than these now mentioned have the power of multiplying their petals by cultivation at the expense of the



Fig. 338.—Polyandria Monogynia.

stamens (page 114); but they are of value, inasmuch as the number is either the original one, or some multiple of it.

The order *Pentagynia* contains five genera of beautiful plants, which have from two



Fig. 339.

Polyandria Monogynia.



Fig. 340.

Polyandria Pentagynia.



Fig. 341.

Polyandria Polygynia.

to six pistils, and includes the splendid *Pæonia* or *Pæony*, *Delphinium* or *Larkspur*, *Aconitum* or *Monkshood*, *Aquilegia* or *Columbine*, and the *Stratigotes*.

There are nine genera in the order *Polygynia*, each of which have an indefinite number of pistils; and many of these are remarkable for their sombre beauty. Thus there are the *Clematis*, *Anemone*, *Helleborus* or *Hellebore*, *Adonis*, *Ranunculus* or *Crowfoot*, *Thalictrum* or *Meadow-rue*, *Caltha Palustris* or *Marsh Marigold*, *Trollius*, and *Ficaria*.

This class is therefore remarkable for its powerful medicinal or poisonous properties—properties which pervade the class as a whole—and for its flowers, of a deep colour and sombre beauty. Amongst the former we may mention the *Papaver*, which supplies so vast a quantity of *Opium* (page 51), *Helleborus Niger* or *Black Hellebore*, and *Aconitum*, all of which still supply medicinal preparations; whilst the *Chelidonium*, *Delphinium*, *Ficaria*, *Ranunculus*, and several others, are known to be poisonous. The *Tilia* affords a delicious scent when in bloom; whilst the flower of the *Nymphaea Alba*, *Pæonia*, *Helianthemum*, *Delphinium*, *Aquilegia*, *Anemone*, and *Adonis*, may well take rank amongst the most favourite productions of our gardens and ponds. The *Nymphaea* is also remarkable as yielding beautiful stellate cells (page 11); whilst the *Papaver* and *Chelidonium* possess a large quantity of laticiferous tissue (page 29) and milky juices. The *Ranunculus* is the only plant bearing a true nectarium on the claw of its petal (page 69).

CLASS XIV.—DIDYNAMIA.

We have now passed in review all the classes which are founded simply upon the number of stamens and their position, and proceed to those which are based on more complex phenomena. The one now under consideration has only one other element added to that of number—*viz.*, the relative length of the stamens, not as an accidental but an essential fact. The class *Didynamia* is characterized by having two long and two short stamens (Fig. 223), and is divided into two orders—*viz.*, *Gymnospermia*, in which the seeds do not exceed four in number, and appear to be, but really are not, naked at the base of the flower; and *Angiospermia*, having the seeds in

a manifest capsule. It is requisite to remark, that when Linnæus founded his classification, the seeds in the order *Gymnospermia* were believed to be naked; but more recent investigation has shown that they were inclosed in a flattened two or four-celled ovarium. This, therefore, is an incorrect division of the class; but it has its value, since the seeds, as they lie at the bottom of the ovarium, *seem* to be naked.



Fig. 342.

Fig. 342.—*Didynamia Angiospermia*.

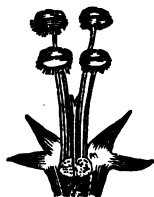


Fig. 343.

Fig. 343.—*Didynamia Gymnospermia*.

There is a further general characteristic of this class—*viz.*, the labiate or bilabiate corolla (page 115), which is found in the major part of its members.

There are thirty-four genera, and eighty-five species, in the class *Didynamia*, and

of these twenty genera are arranged in the order *Gymnospermia*. The calyx is two-lipped in six genera—*viz.*, the *Origanum* or Marjoram, *Thymus* or Thyme, *Prunella*, *Scutellaria*, *Melittis*, and *Clinopodium*; but it is nearly regular, and divided into five segments in the major part of the order, as the *Mentha* (Peppermint, Spearmint, Bergamot-mint, Pennyroyal, &c.), *Nepeta* or Catmint, *Marrubium* or Horehound, *Betonica* or Wood Betany, *Leonurus*, *Glechoma* or Ground Ivy, *Lamium* or Dead Nettle, *Galeopsis*, *Teucrium* or Wood Sage, and others. Nearly the whole of the members of this order are common way-side and water-side plants; but they possess valuable medicinal properties, as in the essential oils found in little reservoirs of the leaves of the *Mentha*, *Origanum*, and *Thymus*; and a bitter principle, which is well known to herbalist housewives, residing in the *Marrubium*, *Betonica*, and others. It is probable that no member is decidedly poisonous.

The order *Angiospermia* differs not only in having an evident capsule, but in the possession of poisonous qualities, at least in several of its members, and is an instance in which plants of diverse affinities have been improperly arranged together under the same head, simply because one point in their organization seemed to indicate a resemblance.

The number of sepals is again a mark of distinction. Thus the genus *Orobancha* has but two sepals, whilst the *Euphrasia* or Eye-bright, *Rhinanthus* or Yellow Rattle, *Lathræa*, *Bartsia*, and *Melampyrum*, have four segments of the Calyx, and eight have the Calyx five-cleft. The last division contains the most important members of the order, and of these the *Digitalis*, or Foxglove, takes precedence. That plant yields a product from its leaves which is of great value in medicine, and which on many occasions has inadvertently produced death. There are also the *Scrophularia* or Figwort, common in ditches and on banks, *Antirrhinum* or Snapdragon, *Linaria* or Toad Flax, *Pedicularis* or Lousewort, and the modest *Linnæa Borealis*, named after the great founder of this system.

None of the members of this order possess the aromatic properties mentioned in the preceding order; but there are several which add much to the gaiety of our fields and shady lanes. In neither order are there any plants which afford nutriment to man.

CLASS XV.—TETRADYNAMIA.

This class resembles the last, inasmuch as it has stamens of different lengths; but it differs in having four of them long and two short (Fig. 344). The two short ones are

placed at the sides of the others, and the whole are inclosed in a flower, which has invariably four petals, arranged in the form of a Maltese cross, and hence termed Cruciate (Fig. 344). Upon the whole it is a well-defined and arranged class, and may be readily distinguished by the construction of the flower and the pod-like seed vessel which its members possess. It is divided into two orders by somewhat indefinite boundaries—*vis.*, *Siliculosa*, signifying a short pod (Fig. 345); and *Siliquosa*, indicating a long pod (Fig. 346). There are twenty-eight genera and sixty-eight species in the whole class.

The order *Siliculosa* is again subdivided into such members as have the pod entire at the top, and others in which the pod is there notched. The former comprehends ten genera, amongst which are the *Cochlearia Armoracia* or Horse-radish, with other species of the same genus, *Crambe Maritima* or Seakale, *Cakile* or Sea Rocket, and *Subularia* or Awl-wort; whilst in the latter there are *Thlaspi* or Shepherd's-purse, *Iberis* or Candy-tuft, and *Lepidum* or Pepper-wort.



Fig. 344.—Tetradynamia.



Fig. 345.—Sicululosa.



Fig. 346.—Siliquosa.



The second order, *Siliquosa*, contains fourteen genera, and amongst them are plants of greater interest. Thus there is the *Brassica* (Cabbage, Rape, Turnip, Navew, and Seakale), *Sinapis* or Mustard, *Raphanus* or Radish, *Nasturtium Officinale* or Watercress, *Barbarea* or Winter Cress, *Arabis* or Wall and Rock Cress, all of which are useful edible plants; *Cardamine* or Ladies' Smock, and other species, *Matthiola* or Stock, and *Cheiranthus* or Wall-flower, which are favourite indigenous flowers.

The class *Tetradynamia* is therefore ranked amongst the most useful of our vegetable productions, since it supplies much of the green vegetable food used by man, as well as condiments and aromatic perfumes. The nutritive properties of the *Brassica* or Cabbage are computed as 1 to 16 of Horse Beans, Lentils, Peas, and Haricots; 1 to 8 of Wheat and Oats; 2 to 1 of Turnips, and of equal proportions to Carrots and old Potatoes; and is chiefly due to the relative quantities of starch contained within their cells (page 32).

CLASS XVI.—MONDELPHIA.

This and the succeeding classes are founded upon another feature in connection



Fig. 347.

Monodelphia Pentandria.



Fig. 348.

Monodelphia Polyandria.



Fig. 349.

Monodelphia Decandria.

with the stamens—*vis.*, the adherence of their filaments, so as to produce one, two, or

more sets. In the small class, now under consideration, the filaments are united together into one bundle, which may consist of five stamens, as in *Erodium* or *Stork's bill*; of two stamens, as in the allied genus *Geranium*; or of an indefinite number of stamens, as the *Malva* or *Mallow* (Fig. 219), *Althæa* or *Marsh Mallow*, and *Lavatera* or *Tree Mallow*. These four genera constitute the whole class, and are subdivided into the following orders as above intimated—*Pentandria*, *Decandria*, and *Polyandria*. None of them are either edible or poisonous; but the *Malva* and *Althæa* have been employed in domestic medicine on account of the mucilaginous juices which they yield. The indigenous *Geranium*, or *Crane's bill*, offers thirteen species; but, whilst they are interesting wayside herbs, they are infinitely inferior in beauty to the cultivated flowers which more commonly bear that name. The whole class consists of five genera and twenty-two species.

CLASS XVII.—DIADELPHIA.

This is a class of very great importance, and is fitly associated with the *Icosandria*, *Triandria*, and *Tetradynamia*, in supplying nutritive and pleasant food for man and animals. It contains eighteen genera and seventy-four species, and, as a whole, is a tolerably well-associated class of plants. It is characterised by having the filaments of the anthers arranged in two sets (the second set usually consisting of but one filament, Fig. 221); and, as a rule, they are inclosed in the carina or keel of the Papilionaceous corolla (Fig. 213). It is divided into three orders, according to the number of the stamens—*viz.*, *Hexandria*, in which there is but one genus, the *Fumaria*, or *Fumitory* growing in corn-fields; *Octandria*, also consisting of one genus, the *Polygala* or *Milkwort*; and, lastly, *Decandria*, which comprises the remaining genera. The orders *Hexandria* and *Octandria* offer nothing of importance; so that it is to the *Decandria* that we direct our attention. In this order the ten stamens are invariably arranged in

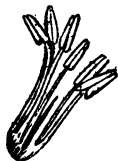


Fig. 350.
Diadelphia Hexandria.



Fig. 351.
Diadelphia Decandria.



Fig. 352.
Diadelphia Octandria.

a set of nine and an odd one, which is not readily separable from the nine by any one ignorant of its separate existence. It usually lies attached to the thin edge or face of the mass of filaments. The following are the chief members of this class:—the *Pisum* or *Pea*, *Vicia* or *Vetch*, *Anthyllis* or *Kidney Vetch*, *Orobus* or *Bitter Vetch*, *Lathyrus* or *Vetchling*, *Hippocrepis* or *Horseshoe Vetch*, *Astragalus* or *Milk Vetch*, *Ervum* or *Tare*, *Trifolium* or *Clover*, *Lotus* or *Bird's Foot*, *Ulex* or *Furze*, and *Genista* or *Broom*; the latter, with the *Ulex*, *Anthyllis*, and *Ononis* being the only instances in which all the stamens are united at their base. The *Pea* is the only member supplying human food under ordinary circumstances; but in seasons of dearth others have been used, and again may be used with great advantage. Nearly all the remaining genera are commonly used as food for animals, and a very few have medicinal properties, as the *Genista* and the *Fumaria Officinalis*. None are poisonous.

They are, for the most part, climbing plants with pinnate leaves, and the midrib

elongated into a tendril or cirrhus (Fig. 185). The prevailing colours of the corolla are yellow or red.

CLASS XVIII.—POLYDELPHIA.

This class consists of one genus, *Hypericum* or St. John's Wort, and eleven genera,



Fig. 353.—Polydelphia Polyandria.

and has the stamens divided into three, four, or more sets (Fig. 220). It is not otherwise of interest. It belongs to the order *Polyandria*.

CLASS XIX.—SYNGENESIA.

This is the largest class of plants in every Flora, and is one of exceedingly well-defined characters. It is also one of some difficulty to the young botanist in determining the species, and even some of the genera; but the mere class-characters are, even to him, of most ready discernment. Its distinguishing feature is the union of the anthers (not necessarily of the filaments also) into a tube through which the pistil passes (Fig. 222). The flowers are also arranged on a capitulum or head, and, in many instances, those of the margin or ray differ in size, or other particulars, from those of



Fig. 354.

Polygamia Equalis.



Fig. 355.

Polygamia Superflua.



Fig. 356.

Polygamia frustanea.

the centre or disk; and hence the flowers of the head are frequently divided into florets of the ray and florets of the disk. The whole florets are surrounded by an involucre of bracts, and each separate floret has a small calyx, which is commonly chaffy. The part upon which the flowers are placed is called the receptacle (Fig. 193). There are forty-one genera, and one hundred and thirty-three species.

This class is divided into three orders. The first is *Polygamia Equalis*, in which all the flowers are perfect, having five stamens and one pistil, and producing one seed. It contains 22 genera and 71 species, and is subdivided into three parts, according to the form of the corolla. Twelve genera have all the corollas strap-shaped. Such are the *Cichorium* or Chicory, the root of which is ground to powder, and used as a substitute for Coffee; *Lactuca* or Lettuce, which in its wild state is poisonous, but

when cultivated may be eaten with impunity ; Prenanthes, or Wall-lettuce ; Leontodon taraxacum or Dandelion, with milky medicinal juices ; Sonchus or Sow Thistle ; Hierac-



Fig. 357.

Detached floret of the ray in the *Polygamia Superflua*.



Fig. 358.

Polygamia Equalis.

cium or Hawk Weed ; Apargia or Hawkbit ; and Tragopogon or Goat's Beard. The ten remaining genera have all the corollas tubular ; six with the florets spreading so as to form a hemispherical head and face, with the florets lying parallel and crowded together, and forming nearly a level surface at the top. Amongst the former are the Carduus and Oniscus, two forms of prickly thistle, and Aretium or Burdock ; and of the latter are the Bidens or Bur Marigold, Diotis, Eupatorium, and Chrysocoma.

The second order is *Polygamia Superflua*, in which all the florets are fertile ; but yet in many cases those of the ray have pistils only. The marginal florets appear wanting in the Artemisia or Wormwood, Tanacetum or Tansy, Gnaphalium or Cudweed, and Conyza or Spikenard ; whilst they are developed, and have a strap-shaped figure, in all the remaining orders. Amongst the latter are found the modest "wee crimson tipped flower," the Bellis Perrennis, Tussilago farfara or Colt's-foot, Anthemis or Camomile, Achillea or Millefoil, Senecio or Groundsel, Aster or Starwort, Chrysanthemum or Ox-eye, and Corn Marigold, Pyrethrum or Fever-few, Solidago or Golden Rod, Inula or Fleabane, and Cineraria or Fleawort.

The third order is called *Polygamia Frustranea*, and has perfect and fertile florets of the disk ; but the florets of the ray have neither stamens nor pistils, and hence the term "Frustranea." The Centaurea, or Centaury, is the only genus, with its seven species.

On taking a review of this extensive class we find that the Lettuce, in its cultivated state, and the dried root of the Chichorium, are the only members which afford nutriment to man. Certain others, as the Sonchus, Leontodon, Carduus, Oniscus, and Senecio are eaten by various animals. Many members have been more or less employed medicinally, and it is probable that medicinal properties are possessed by the whole class. Those which have been most commonly used are the Anthemis, Tussilago, Artemisia, Leontodon, Hieracium, and Inula. Some of these, with the Lactuca and many other members of the class, abound in Laticiferous tissue and milky juices ; and to these may chiefly be attributed the medicinal effects of the plants. They grow exclusively, or nearly so, on dry land, and many of them in waste places. But few have been thought worthy of horticultural cultivation.

CLASS XX.—GYNANDRIA.

This is a very curious class of plants, and at the present day are very fashionable. In this country they grow chiefly in meadow lands and moist soils ; but in tropical

regions they are beautiful parasites upon decaying trees. No more splendid conception of a flower can be obtained than that which is offered by some members of this class now collected in the Royal Gardens at Kew. The class is distinguished by having the stamens situate upon, or connected with, the style or other part of the pistil. There are three orders—*Monandria*, *Diandria*, and *Hexandria*; but all the British genera belong to the first, except *Cypripedium*, which has two stamens, and *Aristolochia*, which has six stamens.

The order *Monandria* has ten genera, while the whole class consists of twelve genera and thirty-seven species. The anther is fixed, terminal, and permanent in the *Epipactis*; and moveable and deciduous in the *Malaxis* and *Corallorhiza*. It is parallel to the stigma, and of two cells close together in the *Neottia*, *Goodyera*, and *Listera*; and either of two vertical cells; permanent, fixed to the summit of the style in *Orchis*, *Acera* or Green Man Orchis, *Ophrys* or Fly Orchis, and *Herminium* or Green Musk Orchis.

Our native specimens of this class are not especially interesting, except the common *Orchis*, with its variegated corolla and green leaves spotted with black, as it is growing on a rich moist meadow. They are not used as food, except the so-called tubers of a few members which have yielded an amorphous form of starch. The general characteristic of the class is acidity; but they are not employed in medicine. The whole class is peculiar, inasmuch as from the conformation of their sexual organs they need the intervention of an insect, as the Bee, to carry the pollen from the anther to the stigma, and ensure fructification.



Fig. 359.
Gynandria
Hexandria.

Fig. 360.
Gynandria
Diandria.

Fig. 361.
Gynandria
Monandria.

CLASS XXI.—MONŒCIA.

In each of the preceding twenty classes every flower has been bisexual, and consequently every tree bearing flowers must have them in this hermaphrodite condition. The three following classes are exceptions to the general rule, and have flowers of one sex or of two sexes, and on the same or on different trees. In the class *Monœcia*, the flowers are unisexual, some having stamens only and others only pistils on the same plant. It is a



Fig. 362.—*Monœcia Monodelphia*.

highly important class, since it contains a considerable number of our forest trees. It is divided into seven orders—viz., *Monandria*, *Diandria*, *Triandria*, *Tetrandria*, *Pentandria*, *Polyandria* (more than five stamens), and *Monodelphia* (filaments united into one brotherhood), and together contains twenty-five genera and one hundred and eight species.

The order *Monandria* (one stamen) possesses but two genera—the *Euphorbia* or

Spurge, which is a common weed on waste land, and the Zannichella. Triandria is chiefly occupied by the Sedges, under the names of Carex, which alone claims sixty of



Fig. 363.
Monœcia Diandria.



Fig. 364.
Monœcia Monandria.



Fig. 365. Fig. 366.
Monœcia Pentandria. Monœcia Tetrandria.



Fig. 367.—Monœcia Triandria.

the whole hundred and eight species found in the classes Typha or Reed Mace, and Sparganium or Bur-reed; all of which, with the Elyna, grow in marshy and muddy places.

The order Tetrandria (four stamens) has five genera—viz., Alnus Glutinosa or Common Alder-tree, Buxus Sempervirens or Box-tree, Urtica or Stinging Nettle, Littorella, and Eriocaulon. The stinging secreting hairs of the Nettle, with their circulation, have been described at page 67. There are only three genera in the order—Pentandria (five stamens); Bryonia or Bryony; Xanthem, and Amaranthus;—whilst the order Polyandria (more than five stamens) has ten genera, several of which are our most important wooded trees. Thus we find the Quercus or Oak, Betula or Birch, Fagus or Beech (Fig. 125), and Chestnut and Corylus or Hazel, amongst trees; with Carpinus, Sagittaria (Fig. 173), Ceratophyllum and Myriophyllum; and, last, the Arum Maculatum or Wake Robin (Fig. 76), with its starch-containing cormus. The valuable Pinus, or Pine-tree, is the sole occupant of the last order, or Monadelphina.



Fig. 368.—Monœcia Polyandria.

It is scarcely possible, in so heterogeneous an assemblage of plants, to fix upon any leading common characteristic; but although no member, except the corm of the Arum, and the nuts of the Fagus, Quercus, and Corylus, offers anything for the food of man or beast, neither is any, except the Oak-bark, employed in medicine, it is highly probable that valuable astringent and perhaps acid properties are common to them all. The

Betula yields a fermenting juice, from which a good wine is produced (page 23); and the *Pinus* affords turpentine and resins: but it is the wood which this class yields that contributes to its value.

CLASS XXII.—DICECIA.

This agrees with the former in all the flowers being unisexual, and having either stamens or pistils alone; but it differs in this respect, that the two sexes occupy different trees. Thus one plant has wholly male flowers, and another has exclusively female

Fig. 369.—*Dicecia Triandria*.Fig. 370.—*Dicecia Icosandria*.Fig. 371.—*Dicecia Enneandria*.

ones. It contains fourteen genera and eighty-two species, divided into twelve orders, —*viz.*, *Monandria*, *Dianthia*, *Triandria*, *Tetrandria*, *Pentandria*, *Hexandria*, *Octandria*, *Enneandria*, *Decandria*, *Icosandria*, *Polyandria*, and *Monodelphia*. This extreme division of its contents clearly proves that it possesses very heterogeneous materials.

Fig. 372.—*Dicecia Octandria*.Fig. 373.—*Dicecia Pentandria*.Fig. 374.—*Dicecia Hexandria*.

The order *Dianthia* is occupied by the genus *Salix*—a genus which affords sixty-four of the eighty-two species of the class. It is known by the catkin inflorescence described at page 166. *Triandria* and *Tetrandria* have three genera each; and of these only one

Fig. 375.—*Dicecia Dianthia*.Fig. 376.—*Dicecia Monandria*.Fig. 377.—*Dicecia Dodecandria*.

of the latter, *Viscum Album*, or Mistletoe, deserves mention. The valuable and scarce *Humulus*, or Hop, occupies the outer *Pentandria*; and *Tamus*, or Black Bryony, the order *Hexandria*. *Populus*, or the Poplar-tree, is found in *Octandria*; and *Mercurialis* and

Hydrocharis in Enneandria. Coniferous trees monopolize the last order, Monodelphia—*vis.*, Juniperus or Juniper, and Taxus, or Yew.



Fig. 378.—Diececia Decandria. Fig. 379.—Diececia Polyandria. Fig. 380.—Diececia Monodelphia.

The *Salix* and the *Populus* are capable of yielding a medicinal substance, which is said to be a good substitute for Quinine; the *Juniperus* an oil which is employed both medicinally and in the preparation of Hollands; and the *Humulus* a bitter principle, which should be used in the manufacture of ale, and a narcotic principle which is employed in medicine. The *Taxus* is one of our most enduring trees, and has been known to live upwards of two thousand years. The latter plant offers glandular woody tissue, with a spiral fibre (Fig. 60). The Mistletoe Berry, *Viscum Album*, is an essential element in our Christmas arrangements, and has been so for many ages. The plant is one of those which took part in the ancient Druidical rites. The whole class possesses acrid or narcotic acid poisonous properties.

CLASS XXIII.—POLYGAMIA.

This represents a condition of the sexual organs which is intermediate between the two last classes; and has hermaphrodite or unisexual flowers indifferently on the same or on different plants of the same species. It has but one member—the *Atriplex*, a common and valueless weed on dunghills and waste places. It has seven species.

CLASS XXIV.—CRYPTOGAMIA.

The characteristic peculiarity of the members of this class is, that they do not possess sexual organs, or that they so conceal them that they have not as yet been discovered. But very few, comparatively, were known to Linnæus; and of those known in our day, the most beautiful, as well as the greatest numbers, are foreign to our shores. Some of them inhabit the most desolate regions, as the Lichens of Lapland; whilst others abound in tropical regions, as the Tree-ferns, to which reference has already been made. They are commonly known as Sea-weeds, Mushrooms, Lichens, Mosses, and Ferns, all of which are flowerless Sea-weeds.

The term *Algæ* is a comprehensive term, capable of wider signification than the corresponding one of Sea-weeds, by which it is commonly represented in our language. It comprehends a very large proportion of the lowest division of the vegetable kingdom, or that which seems to be almost common ground between the lowest forms of both vegetable and animal organization. It is now commonly divided into several groups, as the Brittle-worts, Confervas, true Sea-weeds, Rosetangles, and Charas.

Brittle-worts (Diatomaceæ and Desmidiæ) constitute the slime which is found upon the surface of stems, and are commonly so minute as to be microscopic objects. They are fragmentary, brittle bodies, generally bounded by right lines, and of a green colour; and with the slime in which they nestle afford protection and food to microscopic animalcules. Many of them inhabit salt, and others the fresh waters, and most of them develop starch within their cells. Amongst the chief genera we may mention *Diatonia*,

Desmidiū, Achnanthes, Gomphonema, Exilaria, Fragillaria, Micromega, Beckleya, Cymbella, Navicula, and Euastrum.

Confervas also inhabit both salt and fresh waters, but are commonly of an olive, violet, and red, rather than a green colour. They consist of a series of cells of various forms, as cylindrical tubular globes, or elliptical, and grow by the subdivision of their cells, and the propagation of spores within the cells. Their forms are extremely varied, and their distribution almost universal. The *Protococcus*, *Hæmatococcus*, *Porphyra* (stewed and eaten, as Lava), *Ulva*, Common Nostoc, or Star-jelly, *Palmella*, *Conferva*, and *Penicillum*, are genera commonly known.

Fucus, or Sea-weeds, are closely connected with *Confervas* both in structure and situation. They differ in their mode of reproduction, for the reproductive organs are situate without the plant, appearing as little green worts invested by a thin membrane; and the male organs, or antheridia, have the spiral filament, before described under the head of Mosses. Some of them are eatable, and are eaten by various people in the Pacific, as well as in the instances of the *Alaria Æsculenta*, and *Fucus Vesiculosus*, by the inhabitants of Ireland, Scotland, and the northern islands. They are, however, of still greater use to man by affording soda in the impure form of kelp, which is used largely by soap makers and glass manufacturers, and also iodine, which is yielded by many genera, but more particularly by the *Ecklonia Buccinalis* of the Cape of Good Hope, and by many on our own shores.

Rosetangles (Ceramicæ) or the Corallines, are also Sea-weeds, but usually have a rose or purplish colour. They consist of cells of various forms, arranged in one or more rows, so as to produce an articulated frond, and are propagated by spores formed in threes or fours within a mother cell. They are entirely marine; and yield a greater number of genera, which are edible by man or animals, than any other form of Sea-weeds. Of the edible ones we may instance *Plocaria compressa* and *Chondrus crispus*, or Carrigeen Moss; *Rhodomenia palmata*, or Dulse; *Iridæa edulis*; and the *Laurencia pinnatifida*, or Pepper Dulse. The *Plocaria tenax* yields glue and varnish, used by the Chinese in the manufacture of their lanthorns; the *Chondrus crispus* yields size; and the *Rytiphlea tinctoria* produces a valuable dye. This is a very valuable class of plants.

The *Charas* are submersed plants of a green colour, with regularly-branched brittle stems and whorls of small branches or leaves. In some of these, as the *Nitella*, the circulation may be seen in its progress up and down the stem by the aid of the microscope.

MUSHROOMS.

The general term *Fungi* represents the varied members of this extensive class of plants, but very inadequately, since the class comprehends, besides the true Mushrooms or Fungi, Moulds, Morels, Mildews, Blights, and Puff-balls. The members, therefore, vary from a size so minute as to be almost or quite invisible to the naked eye, to a mass much larger than the human head. They grow, for the most part, upon decaying substances, and usually increase in size from within. A few, as the *Agaricus foetens*, are said to possess lactiferous vessels and spiral filaments. The major part of them are, moreover, very ephemeral in their character. Some of them are edible, as the common Mushroom (*Agaricus campestris*), Helvella or Morel, and Tuber or Truffle, all of which, with some others, are commonly eaten both in this country and on the Conti-

nent of Europe. Others, however, are very poisonous; and it is believed that species which are sometimes wholesome become poisonous when grown under other conditions, or eaten by persons of peculiar sensibilities. Upon the whole, it is a class of plants which should be sedulously avoided, although a very considerable number are known to be edible in various parts of the world. The dry rot is due to the *Polyporus destructor*, and other species; the blight of corn to the *Puccinia graminis*; the rust to the *Uredos* and *Pucciniæ*; and the mildew to the *Mucedos* (Fig. 301). They also attack cheese, bread, preserves, fruit, and almost every article of food, and are then known as mould; and it is a curious fact that the presence of any perfume prevents their formation. A few of them are phosphorescent. The number of genera is so vast that it is useless to attempt any very limited selection.

LICHENS.

These are directly opposed to Fungi, inasmuch as they are perennial, and consist of a lobe and leaf-like thallus. They constitute the gray, yellow, and brown stains which give an air of antiquity to the walls of our churches; or they are found on broad patches of a leprous appearance on the trunks and branches of trees. They are useful to man in two modes—first, by affording dyes as described on page 54, and, secondly, as food. The latter quality is found in the *Cetraria Islandica* or Iceland Moss, *Cenomyce rangiferina* or Reindeer Moss, *Sticta pulmonacea*, *Alectoria usneoides*, and various species of *Gyrophora*, which furnishes food to the Canadian hunters. Many others possess medicinal properties of value. It is an extensive family of plants, but hitherto it has not been studied with the care which has been bestowed upon other, but not less valuable and interesting, vegetable productions.

MOSSES.

This great class is subdivided into several portions, and exhibits a degree of organization considerably beyond those to which we have hitherto referred. Amongst the subdivision we may instance the Scale Mosses (*Jungermanniæ*), Split Mosses (*Andræaceæ*), Urn Mosses (*Bryaceæ*), Club Mosses (*Lycopodiaceæ*), Crystal Worts (*Ricciaceæ*), Liver Worts (*Marchantiaceæ*), and Horse-tails (*Equisetaceæ*). In some instances, as in the *Sphagnum* and *Polytrichum*, the male organs may be seen in constant motion in the early spring months, and appear like two thread-like bodies, with one extremity thin and attached, and the other enlarged and free, inclosed within a distinct cell-wall. The same kind of motion is also found in other members of the class, and is due in some degree to hygrometric influence, as has before been described in reference to the Urn Mosses.

The *Crystalworts* are amongst the most diminutive members of the class, and swim or float upon small collections of shallow water, or attach themselves to the mud. They are but few in number. The *Liverworts* are found very abundantly in damp unfrequented places, on the uncovered ground, inclosed by the walls of ruined castles. They consist of a broad frond, which lies upon the soil, and emits roots from its under surface, possessing antheridia and pellate receptacles. They differ from *Crystalworts* in having elaters and involucrate spore-cases.

The *Scale Mosses* (*Jungermannia*, Figs. 294 and 295), possess a far higher degree of organization, having well and symmetrically expanded leaves, and, in many, a long stalk supporting the simple fruit. They abound in tropical regions.

The Horse-tails (*Equisetum*) possess a fistular articulated stem, surrounded by

a layer of hard woody tubes. There are no leaves; but the external articulated organs much resemble them. The fruit is borne on the top of the stem, and consists of a number of masses sessile upon the common rachis. They are widely distributed, and have the peculiarity of containing a large quantity of siliceous matter in their cuticle; so much so, that the *Equisetum hyemale* and other genera are used in the polishing of metals and furniture.

The *Urn Mosses* are small, terrestrial, or aquatic plants, with an axis of growth and minute imbricated leaves, and differ from all other Mosses in the structure of their two kinds of reproductive organs. They are an interesting and extensive division of the family of Mosses, and are more commonly found in temperate than in tropical climes. Wherever there is moisture, even if soil be almost absent, they will grow, and they are the first to cover a barren coast, as they are the last to linger when the atmosphere ceases to be capable of affording nourishment to vegetation. The *Sphagnum*, *Polytrichum*, and almost all plants vulgarly known as Mosses, belong to this division.

FERNS.

The highest division of the Cryptogams is that known as Ferns (*Filices*), a division which, in the degree of its organization, far exceeds that of any yet mentioned. They consist of "leafy plants producing a rhizome, which creeps below or upon the surface of the earth, or rises into the air like the trunk of a tree." When a stem exists it is usually simple, and of even diameter throughout, and bears a tuft of leaves on its apex, after the fashion of Palms and other endogenous plants, and is composed of cellular, woody, and scalariform tissues. The reproductive organs are spore cases, arising from the veins on the under surface, or other part of the leaves; or they are situate beneath the cuticle, which they thus throw up in the form of an *indusium*.

This class is divided into three portions—the *Ophioglossus* or Adder's-tongues, the *Polypodiaceæ* or true Ferns, and the *Danaeaceæ* or Danæants; and of these the middle one, or that of true Ferns, contains nearly the whole of the members of the class. We regret that our space does not permit us to enter into detail into this beautiful, varied, and very interesting tribe of plants; and the more so, that at the present moment the Ferns and the Orchis have attained to an enviable popularity.

The *Adder's-tongues* are minute plants, closely allied to the Club Mosses (*Lycopodiaceæ*), with a hollow pithless stem, containing woody fibre, and possessing leaves with netted veins.

Its reproductive organs consist of spores contained within spore-cases, which are arranged on a spike on the sides of a contracted leaf. The *Danaeaceæ*, on the other hand, are true dorsiferous Ferns, with reproductive organs sunk within or seated upon the back of the leaflets. There is also, as in the Adder's-tongue, an absence of the elastic ring, which is indicative of true Ferns. Both of these divisions of Ferns are very small, containing together only nine genera.

The true Ferns or *Polypodiaceæ* (vaguely designated *Filices*) are distinguished by the presence, on the spore-case, of a ring or band of coarse meshes distinctly different from the tissue of their sides, and too strong to be broken through, when the case opens to discharge its spores. A few genera are considered edible, as, for example, the *Pteris esculenta*, *Cyathea medullaris*, *Diplazium esculentum*, and *Gleichenia Hermannii*. The Java Fern is also nutritive, whilst the *Aspidium fragrans* has been employed as a substitute for tea, and the *Pteris Aquilina* and *Aspidium Filix-mas* have been used in the manufacture of beer. The genera are very variously distributed over the face of the

earth, and in different localities bear very various relations to the total genera of plants ; but it is certain that the most elegant, as well as the most lofty specimens, are not indigenous to our islands. Amongst the English genera we find the *Polypodium*, *Wood-sia*, *Aspidium* or *Shield Fern*, *Cystea* or *Bladder Fern*, *Asplenium* or *Spleen Wort*, *Scolopendrium* or *Hart's Tongue*, *Blechnum* or *Hard Fern*, *Pteris* or *Brake*, *Adiantum* or *Maidenhead*, *Trichomanes*, *Hymenophyllum*, and *Osmunda* or *Flowering Fern*.

Before quitting the Linnæan arrangement, it may be advantageous to our readers if we give a few simple directions as to the proper mode of examining a plant under this system.

The first aim of the botanist will be to determine the class and order in which the plant under examination is arranged. He will, therefore, at once direct his attention to the flower (if the plant do not belong to the last order, or that of *Cryptogamia*), and see if both stamens and pistils are present together. If he find such to be the case, the plant is bisexual ; but since, in the twenty-third class, or that of *Polygamia*, both unisexual and bisexual flowers exist on the same plant, he will glance at other flowers on the same stem, and ascertain if such be the case on the plant in question. If all the flowers are bisexual, he will then attend to the number, length, and position of the stamens, which, in a majority of instances, will at once direct him to the class sought for. Thus, if there be two long and two short stamens in all the flowers, the plant is *Didynamous* ; and if there be four long and two short stamens universally, he will refer it to *Tetradynamia*. He must not, however, expect that in any plant all the stamens shall be of precisely equal length ; but although such be the case, this will constitute no important source of fallacy, since half-a-dozen examinations of the stamens of a *Didynamous* and a *Tetradynamous* plant would enable him to perceive that the diversity in length is not an accidental circumstance, but one which, from its constancy and relative proportions, is very characteristic. Let him select the common *Mint* or *Fox-glove*, as an example of *Didynamia*, and the *Mustard* or *Water-cress* as an illustration of *Tetradynamia*.

This point having been passed, and having found that all the stamens are of nearly equal length, he will next ascertain if they are separate from each other down to their point of insertion. We will first suppose that their foot-stalks or filaments are connected together through a distance more or less great, but yet so restricted that the anthers are free ; the plant will belong to one of the three classes—*Monodelphia*, *Diadelphia*, or *Polydelphia*. He will next seek to determine if they form one set, or two or more sets. To this end, he should take away the corolla, and any other parts which may interfere with a due inspection of the base of the stamens ; and then with the fingers try if any part of the mass of stamens will come away naturally, as it were, from other parts. Thus the *Hypericum*, or *St. John's-wort*, possesses a large number of stamens, which, on being gently pulled asunder at their bases, are readily detached in three or four masses ; the stamens in each mass being still adherent, and each mass attached to its neighbour simply by the cohesion of apposition. Such a plant, then, belongs to the order *Polydelphia*. Again, the *Pea*, *Bean*, or *Vetch* presents the stamens arranged precisely as exhibited in Figs. 221 and 351, except that the single stamen is not so much detached from the mass as represented in these drawings ; and by examining the concavity of the mass of stamens with the finger-nail, or any pointed instrument, the odd stamen will be discovered lying close to the mass, but not connected with it. This indicates the class *Diadelphia*. This class of plants has almost universally the

papilionaceous form of corolla, which, on being appreciated, will, in the great majority of instances, alone suffice to indicate the class. Lastly, when the stamens are united together by their filaments, as above indicated, but cannot be divided into distinct bodies, as in the Geranium and Mallow, the plant is Monodelphous.

There may, perhaps, be some little difficulty to the young botanist in determining whether plants belonging to the Monodelphian and Polydelphian classes have really their filaments so united; but a very little attention and practice will show that the filaments are not separate on both sides down to their base, and, moreover, the characteristic appearance of the stamens as a whole will soon be appreciated by the student.

If the filaments be free, but the stamens united together, the plant will belong to the order Syngenesia; but as all this great class of plants have aggregated florets placed as a capitulum (Figs. 354, 355), their appearance is so characteristic, that, after a very short space of time, the student will not need to examine the stamens to determine the classification of the plant.

The only other exceptional class is that of Gynandria; and it is not one which can be very intelligibly described upon paper. It is composed of the Orchis tribe of plants, and those closely associated with it; and if the student will regard attentively the combined stamens and pistils, and the *toute ensemble* of the flower of any Orchis, as of those growing in our moist meadows, or those now universally found in hot-houses, he will speedily learn how to distinguish this class in an instant, without, however, being so readily able to explain it to another.

We have considered the foregoing exceptional cases first, not because they are the most numerous in the great assemblage of plants, but because they have readily recognised characteristic peculiarities, and because, having excluded them from consideration, the student may give undivided attention to the greater number which yet remain. If the stamens are free from each other throughout, and are nearly of equal size (differing somewhat according to the progressive development of the season), and are not more than ten in number, the plant may be at once referred to its proper class, as Monandria, &c.; but if the number should be indefinite—say fifteen, or any larger number—the plant may be either Icosandrous or Polyandrous. To determine to which of the two classes it is to be referred, simply tear away the corolla and calyx piece by piece; and if the stamens come away with the pieces—as would be the case in the Rose, Hawthorn, and Apple—the plant is Icosandrous. This indicates that the stamens are Epigynous; whilst the Hypogynous mode of insertion is characteristic of the class Polyandria. The Rose may illustrate Icosandria, and the Crow-foot (*Ranunculus*) Polyandria.

The small class of Dodecandria is not so easily recognised by its stamens, since the number is considerable, but somewhat indefinite.

The foregoing directions will suffice as a guide to the student, except in the comparatively few instances in which the number of stamens has been unduly increased or diminished. The increase is less common than the decrease; and is chiefly restricted to the classes Triandria and Pentandria, or all the classes below Pentandria, and is usually to the extent of a duplicate of the original number. Thus a Triandrous plant occasionally has six stamens, and a Pentandrous one has ten stamens. This little difficulty is overcome by examining other flowers on the same plant, or on a similar plant growing near to it, when the normal number of stamens will be found on a majority of them.

When there is a decrease in the number of stamens, it is usually accompanied by a corresponding and equal increase in the number of the petals, and is for the most part restricted to the two classes Icosandria and Polyandria. If in either of these cases the petals are more than five in number, it may be inferred that the innermost rows have been produced at the expense of the outermost rows of stamens. This, however, constitutes no sort of difficulty, since a sufficiently large number of stamens remain to enable the student to determine the class, except in the case of cultivated plants, when the whole of the stamens may have been converted into petals, as in the perfect Rose (Fig. 207). We therefore advise the beginner to avoid all garden flowers, and examine only those which are met with in their wild and uncultivated state.

The classes Monœcia and Dioecia are not so readily discovered by a reference to the stamens of the flower, since for the most part the flowers are small, and without gay colours, and the stamens are indistinct. He will first strive to ascertain if the flower under examination has stamens or pistils (since it is unisexual), and will find that the pistils occupy a central position, and have an expanded base or ovary, whilst the stamens are usually arranged in a circle, leaving a central vacuity, and are surmounted by a swollen part or anther. This is not at all times an easy diagnosis in practice; but it will aid the student to remember that, for the most part, the members of these classes are large wooded trees. There are many exceptions to this rule, as in the cases of the Stinging Nettle and the Sedges; but the exceptions are perhaps less difficult of diagnosis than the members which may constitute the rule.

Having thus discovered the Class to which the plant belongs, he will next seek the Order; and to this end will chiefly regard the pistils. This will apply perfectly to all plants having the stamens separate from each other, and of equal size; and in such cases it suffices to count the number of pistils only. The orders of the first fourteen classes are determinable in this way; but beyond these, the pistil is not regarded in determining the class. If, therefore, the plant belong to the class Polyandria, or any other preceding class, simply count the number of pistils in order to find the order; but if it be Didynamous, or Tetradynamous, the student must notice the character of the seed-vessel or pod. Thus, when a Didynamous plant has an evident more or less conical ovary, as in the Digitalis and Scrophularia, the order is Angiospermia; but if, after tearing away the corolla, he look deeply to the bottom of the calyx, and find a flattened ovary with one or two transverse lines on its surface, indicating a division of the ovary into two or four parts, as in the Mint, the plant belongs to the order Gymnospermia. The diagnosis of the two orders in Tetradynamia is somewhat more arbitrary; for it depends simply upon the size of the pod. A long pod, as of the Pea, indicates the order Siliquosa; and a short, and for the most part a comparatively broad one, marks the order Siliculosa.

The orders found in the classes Monodelphia, Diadelphica, and Polydelphia, and also Gynandria, Monœcia, and Dioecia, are determined by counting the number of the stamens; whilst those of Polygamia are simply Monœcia or Dioecia. The numerous class Syngenesia is divided into orders without exclusive reference to its stamens or pistils, but simply by the arrangement of the florets upon the capitulum. Thus, in the order Polygamia Æqualis, all the florets are equal, and all possess both stamens and pistils; whilst the term Superflua indicates that the florets are divided into those of the ray and of the disk, and that the former have pistils only. In the third order, or that of Frustranea, the florets of the ray are destitute of both stamens and pistils.

Thus we have not been able to give such directions as shall enable the student to

determine the order of a plant without having first discovered the class in which it ought to be placed; for such was not the intention of Linnæus when he founded his arrangement. He will, therefore, first find the class and then the order; but, in the great majority of instances, both will be perceived by the same glance.

But both the class and the order are alike dependent upon the presence of a flower; and therefore it will be in vain for the inexperienced student to attempt to discover them, except at the proper season of the year, when the plant is in flower, and whilst the flower remains perfect.

These two preliminary circumstances are usually got over without any difficulty; but the next stages in the investigation require a far wider range of observation. It is now necessary to examine, more or less minutely, every part of the plant. Thus its height, and the size and form of its stem and root, must be noticed, distinguishing between herbaceous or annual plants and woody, or those which are more or less perennial. If the plant be herbaceous, it is necessary to ascertain if the stem be hollow, and if it have any flutings or other markings upon its external surface; and in all cases it is requisite to glance hastily at the general arrangement of the leaves upon the stem or plant. In reference to the root of herbaceous plants, it may further be observed that its form must be noticed—that is, as to whether it is tuberous or fibrous, or præmorse, or any other of the forms previously indicated.

The leaves and the parts constituting the flower are, however, those parts from which the distinguishing features of plants are usually drawn.

The form of the leaf is a prime consideration; and the student must notice if it is round, oval, pointed, or otherwise, and if equally so on each side of the midrib, and also whether its edge is entire or divided in various ways. The size, thickness, and colour should be regarded, and also the character of its surface, as to whether it is smooth or rough, and if the hairs are distributed evenly over the two surfaces, or only over one or over a part of one; and also the precise characters of the hairs, as to whether they are like bristles or down, or otherwise. Lastly, its venation demands attention in order to show if the plant be an exogen, as indicated by the reticulated venation, or an endogen, as shown by its parallel veins. The petiole, in like manner, must be examined, and afterwards the inquiry made if the leaf is caducous or permanent, and if it altogether falls off the stem or withers upon it, as is the case in the *induviate* condition referred to in its proper place. The points in which leaves differ from each other are wonderfully numerous, probably extending to some hundreds; and all of these are made use of in describing the characters of plants. Most of them are happily recognisable by the very apt terms with which this science, above all others, has been supplied; so that any inexperienced student, with a descriptive manual in his hand, would scarcely fail to understand the terms which are employed to enable him to refer any plant to its proper place.

The flower is, as we have already shown, a compound organ, and offers a great many objects to the student's attention. First, regard the general arrangement of the flowers upon the plant, and inquire if they are placed in the axils of leaves (axillary) or otherwise, and if they terminate a branch rendering it *determinate*. Then somewhat restrict the range of observation, and notice that arrangement of the flowers upon the stem which constitutes the inflorescence, and afterwards proceed to consider an individual flower, regarding the envelopes from without inwards. The calyx and corolla may both be monosepalous or polysepalous. If they are monosepalous, the form must be noticed as to whether it is rotate or bell-shaped, or otherwise, and its free border inspected, to ascer-

tain if it is entire or variously divided; and if divided, the figure, number, and depth of its divisions will require attention. When a tube exists, as is common in monopetalous corollas, its length, width, and general proportions must be observed, and also any hairs or other organs which may defend the entrance into it. When these envelopes are polypetalous, the same degree of attention must be given to each sepal and petal as above directed with regard to the leaves, except that these organs are usually of more delicate organization than leaves. But whether they consist of one or of many pieces, it will be equally necessary to notice their texture, colour, and relative length (that is, whether the corolla is longer or shorter than the calyx), and whether either or both are caducous or permanent; and, if caducous, to ascertain whether it falls early, and in one or in many pieces. Should there be any appendages to these parts—as the corona of the *Narcissus*, or the nectarium of the *Ranunculus*—they must be carefully noticed and examined. It will further be proper to notice the relations which these parts are said to bear to the ovary,—that is, as to whether they are superior or inferior; and also their relation with the stamens, as to whether those latter organs are attached to them or not.

In these directions we have already referred, to some extent, to the stamens and pistils; but further detail is now necessary. Thus, in reference to both, the presence or absence of the foot-stalk (filament and style) must be determined; and if it be present, its length, figure, and colour should be observed. In but few instances is it coloured; but in many the figure is not uniformly cylindrical, but tapering upwards, or awl-shaped; and in some instances it assumes a foliaceous character.

The anther demands minute attention, in order to show the mode of its attachment to the filament, its figure, and the number of the cells into which it is divided. The pollen seldom calls for examination under the Linnæan system of classification; but if the examination be made at a period when the pollen is ripe, and lying loose upon the anther and other parts of the flower, there can be no difficulty in ascertaining its colour, size, and general configuration. Its minute anatomy is a subject of great difficulty, and one into the consideration of which it is not needful that the inexperienced student should enter.

The style offers perhaps fewer points for observation than the anther, since its structure is more simple. It will be proper first to notice its divisions, and the mode in which those divisions, if any, are arranged; and then to observe carefully its general configuration, and the precise nature of the exposed free surface upon which the pollen is destined to fall. Its internal anatomy, or that of its conducting tissue, is not of importance to this part of our subject. The ovary must be minutely examined; and in order to do that it will be needful to cut it through transversely, and then ascertain the number of the cells of which it is composed, and that of the seeds lying within each cell. It is not uncommon to find fewer seeds than cells, owing to abortion, and that also must be ascertained. The external configuration of that organ will, of course, call for attention, and also any bodies which are sometimes met with, as the disk at or near to its base.

The seed is to be observed chiefly on account of its external configuration, and its number in relation to the cells in which it lies. The Linnæan arrangement calls but little for any account of its internal anatomy; and, with the exception of the number and general nature of its Cotyledons, and some slight reference to the albumen, it will not be necessary for the student to regard it. The fruit must be noticed in a general manner—that is, as to whether it is succulent or otherwise; and the names which have

been referred to when considering that organ, as well as those of more popular employment, committed to memory.

All the foregoing particulars are not necessary to enable the student to determine the *genus* of any plant, since the characteristic of a genus is, that it possesses only certain (perhaps but few) features which are common to a number of other most closely allied plants, which are thence termed *species*. But if any number of plants, say ten, agree in certain features, so that they may be associated under one head, each of these will differ from the others in features of greater minuteness; and, consequently, a more minute acquaintance with all the parts of a plant is more necessary to determine the species than the genus.

In order practically to apply these directions, we will give one or two familiar examples, by way of illustration. Let us first examine the *Myosotis*, or Forget-me-not. This plant will be found to have five stamens and one pistil, and consequently is at once referable to the class Pentandria, and order Monogynia. Having referred to any synopsis of the Linnæan arrangement, the student will find no fewer than forty genera described under Pentandria Monogynia, and therefore will need further characteristics, in order to prevent the necessity of comparing this plant with the descriptions of all these genera. This is effected by noticing that a certain number of these genera have an inferior monopetalous corolla, and two or four naked seeds; and on referring to the *Myosotis* he will find that such is the case with that plant also. This, then, limits his investigation to ten genera, and it will be his duty to read the description of each, beginning with the first, until he finds that one with which the plant in question corresponds. The following are the characters of the *genus Myosotis* :—

“Calyx inferior, of one leaf, deeply five cleft; segments acute, equal. Corolla of one petal, salver-shaped; mouth half closed, with five small valves. Filaments very short; anthers small, oblong. Ovary, four. Style, thread-shaped, central, as long as the tube; stigma obtuse. Seeds egg-shaped, pointed, smooth.”

This description having been found to correspond with the plant under examination, the next step will be to determine the precise species. The student will now find that there are seven species described under that genus, and it will be his duty to compare his plant with the first, and all others, until he finds the one with which it corresponds. This will probably be far less tedious than it at first sight appears, since, immediately he discovers in the description of any of the species any feature which differs clearly from the specimen in his hand, he will not continue the comparison, but at once proceed to the description of the next species. In this way it is possible to examine a dozen species in three or four minutes. Having, however, noticed that the description of the genus and species *Myosotis palustris* corresponds with his plant, he has then discovered that which he had been seeking for—*viz.*, the class, order, genus, and species. The characters of the species are thus described :—

“Calyx funnel-shaped, with short broad segments; leaves oblong, roughish, with close-pressed bristles, root creeping. Roots very long, creeping; stem from six to twelve inches high; clusters many-flowered; two or three together; limb of the corolla sky blue, the valves of the mouth yellow. Perennial; flowers in June and July; grows in marshy places and ditches: common.”

The student will thus be able readily to appreciate the different degrees of minuteness needful to the determination of a genus and a species; he will observe that the difficulty of determining the genus and species is usually in proportion to the number of genera found in the same class and order, and of species under the same genus.

We will now take a more difficult illustration—*vis.*, that of the Stinging Nettle (*Urtica*). We first notice that the flower is deficient in stamens or pistils, and thence that it is not *bisexual*. We then examine other flowers, and ascertain that this is not a mere coincidence, but is universal; and, further, that all the flowers are unisexual, and that on the same tree there are flowers only male, and others only female. Thus we refer the plant to the class *Monœcia*. We now select a male flower—that is, one having stamens only; and finding that there are four stamens, we refer the plant to the order Tetrandria. In this order there are but five genera, and of these one is a tree—the Alder—and another is the common Box (*Buxus*), with both of which the student will be familiar, and know at once that they cannot refer to the plant in question. Moreover, two others, *Littorella* and *Eriocaulon*, are found, by the description of their solitary genus, to grow in lakes and marshy places; and as his plant grew on a bank, or on some waste dry land, he may exclude them, and thus find that he is referred to the only remaining genus, that of *Urtica*. This careless mode of exclusion will not, however, suffice beyond the point of directing immediate attention to the remaining genus, and therefore he will at once proceed to compare the description of the *Urtica* with the characters of the plant in his hand. The following description will suffice to indicate the genus *Urtica* :—

“*Barren (or male) flower.* Calyx of four roundish; concave, equal leaves. Petals none. Nectary central, cup-shaped. Filaments four, awl-shaped, spreading, as long as the calyx; anthers roundish, two-lobed.—*Fertile (or female) flower.* Calyx inferior, of two roundish equal leaves. Corolla none. Ovary egg-shaped. Style none. Stigma downy. Seed one, naked, egg-shaped, somewhat compressed, polished, embraced by the permanent calyx.”

The term *nectary* is here used in the indefinite sense in which Linnaeus employed it, when he assembled very various structures, situate at or about the base of the ovary, under that appellation, and in the sense in which it is still used by systematic works on classification. It is not the true nectary found upon the short claw of the petal of the *Ranunculus*, since the *Urtica* has no petals.

The determination of the species is not difficult, since there are but three species of *Urtica*, all of which have venomous stinging or secreting hairs, and opposite leaves, and the distinguishing features are referred to only two or three points. Thus we will suppose that the plant under examination is the small Nettle, or *Urtica urens*, and that the following description will indicate its characters :—

“Leaves opposite, broadly elliptical, with about five longitudinal ribs; clusters simple. From one to two feet high; bright green, with venomous stings. Annual; flowers from June to October; grows on cultivated ground and waste places.”

Having given these two illustrations, we think that the attentive student will find no difficulty in proceeding with the examination and classification of plants; but we think it needful to append one caution. Do not be discouraged if you have difficulty in referring an unknown plant to its proper place amongst the genera and species; but having given due attention and failed, lay the plant aside, or invite the assistance of some one who may have made further progress in the science. There is no royal road to learning, and the first steps will ever be toilsome and difficult; but, as the student proceeds, he will find that the difficulties gradually and insensibly recede, until, in a short time, he wonders that he ever regarded them for a moment. Do not at first fatigue the mind, and discourage the spirits; but be assured that you, like others, will overcome them.

NATURAL SYSTEM OF PLANTS.

The Natural System of Plants differs from the artificial system now detailed; for it takes into account the whole organization of the plant, with its habits and properties, and is not restricted to one or two particular features. The contrast of the two plans of classification is thus concisely stated by the author of the "Vegetable Kingdom:"—"The natural system of Botany being founded on these principles, that all points of resemblance, between the various parts, properties, and qualities of plants, shall be taken into consideration; that thence an arrangement shall be deduced in which plants must be placed next each other, which have the greatest degree of similarity in those respects; and that, consequently, the quality of an imperfectly-known plant may be judged of by that of another which is well known. It must be obvious that such a method possesses great superiority over artificial systems, like that of Linnæus, in which there is no combination of ideas, but which are mere collections of isolated facts, having no distinct relation to each other. The advantages of the natural system, in applying botany to useful purposes, are immense, especially to medical men, who depend so much upon the vegetable kingdom for their remedial agents. A knowledge of the properties of one plant enables the practitioner to judge scientifically of the qualities of other plants naturally allied to it; and therefore the physician, acquainted with the natural system of botany, may direct his inquiries when on foreign stations, not empirically, but upon fixed principles, into the qualities of the medicinal plants which have been provided in every region for the alleviation of the maladies peculiar to it. He is thus enabled to read the hidden characters with which nature has labelled all the hosts of species that spring from her teeming bosom."—We do not need therefore to hesitate when we confidently recommend this plan of classification in preference to the simple one already given.

As the component parts of a plant are very various, and their relative importance is somewhat a matter of opinion, and, moreover, as plants resemble and differ from each other in so many and minute particulars,—it is no matter for wonder that various natural systems have been devised. Indeed it is not possible for any ten of the most learned men existing to prepare each an original scheme, independent of each other, without producing ten systems instead of one system of classification. There have been already about thirty distinct systems (many of which, however, were simply modifications of one or more preceding); and it is probable that the best one, at the present moment, is so imperfect that it must be amended yearly. The great Linnæus himself gave the outline of a natural system, in which he arranged all the then known plants under sixty-eight heads; but he attached little importance to it. Since his day several others have appeared, which were original, and which have had great influence in the world. The first is that of Adrien de Jussieu, who, in 1789, published an admirable system on the outlines given by our great countryman Ray, in 1703; and to this day De Jussieu's system is held in high estimation. The next great writer on classification was A. P. de Candolle, and he compiled one hundred and sixty-one natural orders out of the three great divisions of plants,—Dicotyledons, Monocotyledons, and Acotyledons, before described. These two systems have been the foundation of all those of more modern

date, including those of Endlicher, who was De Jussieu's great successor, Brogniart, and Lindley.

The difficulty, at the present day, is to make a good selection, and more particularly in a work of this nature, which is to be the handbook of botany to so many thousands of readers—both scientific and non-scientific. Our aim must be to obtain that which, with simplicity, will give the most recent and the most valuable information. On careful consideration we are of opinion that we shall be doing an injustice to our readers, if we fail to make them acquainted with the last one above-mentioned—the system of a distinguished countryman, which, as it is based upon most extensive and usually accurate information, is deservedly supplanting others in the botanical teaching of the British schools.

THE NATURAL SYSTEM, ACCORDING TO DR. LINDLEY.

Before commencing an examination of this system we must beg our readers to bear in mind that a close attention is necessary to the minute parts of the plant, and more particularly of the seed; since, of all organs, that is one possessed of the greatest degree of constancy. We must also give some degree of encouragement to the student by stating, that although this system is not so simple as that previously described, it is yet less difficult than it appears to be. Its difficulty lies at the threshold; and to overcome it the student will have the gratification of gaining much interesting information.

We cannot enter at length into the subject, but shall give an outline of the whole scheme, and such illustration as may be interesting and useful to the reader, and necessary to a comprehension of so extensive a subject. The following is a condensation of Professor Lindley's scheme ("Vegetable Kingdom," p. lv., *et seq.*)

CLASSES.

Asexual, or Flowerless Plants.

Stems and leaves undistinguishable I. THALLOGENS.

"A Thallus is a fusion of root, stem, and leaves, into one general mass, and Thallogens are also destitute of flowers; they are equally without the breathing pores, so abundantly formed in the skin of more complex species; and they multiply by the spontaneous formation in their interior, or upon their surface, of reproductive spheroids, called spores."

Stems and leaves distinguishable II. ACROGENS.

"Beyond Thallogens are found multitudes of species, which, like Thallogens, are not furnished by nature with flowers, but which otherwise approach closely to the higher forms of structure, occasionally acquiring the stature of lofty trees. They have breathing pores in their skin; their leaves and stems are distinctly separated; in some of them those spiral threads, which form so striking a portion of the internal anatomy of a more perfect species, exist in considerable abundance; and finally, they multiply by reproductive spheroids or spores, either formed without the agency of sexes, or, if the contrary, shall be proved at all events not possessing bodies constructed like stamens on the one hand, and embryos on the other. Their stem, however, does not increase in diameter; it only grows at the end, and hence it has given to such plants the name of *Acrogens*."

Sexual, or Flowering Plants.

Fructification springing from a thallus III. RHIZOGENS.

"Foremost among the more perfect races comes a most anomalous collection of species called *Rhizogens*. These plants, leafless and parasitical, have the loose cellular organization of Fungi; a spiral structure is usually to be found among their tissues only in traces. Some of them spring visibly from a shapeless cellular mass, which stands in place of stem and root, and seems to be altogether analogous to the Thallus of the Fungi; and it is probable that they all partake in this singular mode of growth. Their flowers are like those of more perfect plants; their sexual apparatus is complete, but their embryo, which is not furnished with any visible radicle or cotyledons, appears to be a spherical or oblong homogeneous mass."

Fructification springing from a stem.

Wood of stem youngest in the centre; cotyledon single.

Leaves parallel-veined, permanent; wood of the stem always
confused IV. ENDOGENS.

"*Endogens* consist of species whose germination is endorhizal, whose embryo has but one cotyledon, whose leaves have parallel veins, and whose trunk is formed of bundles of spiral and dotted vessels, guarded by woody tubes, which bundles are arranged in a confused manner, and are reproduced in the centre of the trunk."

Leaves net-veined, deciduous; wood of the stem, when peren-
nial, arranged in a circle with a central pith V. DICTYOGENS.

"*Dictyogens* are *Endogens*, but with the peculiarity that the root is exactly like *Exogens* without concentric circles, and the leaves fall off the stem by a clean fracture, just as in that class."

Wood of stem youngest at the circumference, always concentric;
cotyledons 2 or more.

Seeds quite naked VI. GYMNOGENS.

"*Gymnogens* are a division of *Exogens* which, in the sexual apparatus, have no style and stigma, but are so constructed that the pollen falls immediately upon the ovules, a peculiarity analogous to what occurs among reptiles in the animal kingdom."

Seeds inclosed in seed-vessels VII. EXOGENS.

"The class of *Exogens* is composed of innumerable races, having an exorhizal germination, an embryo with two or more cotyledons, leaves having a net-work of veins, and a trunk consisting of woody bundles, composed of dotted and woody tubes, or of woody tubes alone, arranged around a central pith, and either in concentric rings or in a homogeneous mass, but always having medullary plates forming rays from the centre to the circumference, and reproduced on the circumference of the trunk, whence their name of *Exogens*."

CLASS I.—THALLOGENS.—939 Genera; 8394 Species.

ALLIANCES OF THALLOGENS.

1. ALGALAE.—Cellular flowerless plants, nourished through their whole surface by the medium in which they vegetate; living in water or very damp places; propagated by zoospores, coloured spores, or tetraspores. 283 Gen.; 1994 Sp.

Natural Orders.—1. Diatomaceæ, or Brittleworts. 2. Confervaceæ, or Confervas. 3. Fucaeæ, or Seaweeds. 4. Ceramiales, or Rosetangies. 5. Characeæ, or Charads.

2. **FUNGALAE.**—Cellular flowerless plants, nourished through their thallus (spawn or mycelium); living in air; propagated by spores, colourless or brown, and sometimes inclosed in asci; destitute of green gonidia. 598 Gen.; 4000 Sp.

Natural Orders.—6. Hymenomycetes, Agaricaceae, or Toadstools. 7. Gasteromycetes, Lycoperdaceae, or Puffballs. 8. Coniomycetes, Uredinaceae, or Blights. 9. Hyphomycetes, Botrytaceae, or Mildews. 10. Ascomycetes, Helvellaceae, or Morels. 11. Physomycetes, Mucoraceae, or Moulds.

3. **LICHENALES.**—Cellular flowerless plants, nourished through their whole surface by the medium in which they vegetate; living in air; propagated by spores usually inclosed in asci; and always having green gonidia in their thallus. 58 Gen.; 2400 Sp.

Natural Orders.—12. Graphidaceae, or Letter-Lichens. 13. Collemaeae, or Jelly-Lichens. 14. Parmeliaceae, or Leaf-Lichens.

CLASS II.—ACROGENS.—310 Genera; 4086 Species.

ALLIANCES OF ACROGENS.

4. **MUSCALES.**—Cellular (or vascular). Spore-cases immersed or calyptrate (i.e., either plunged in the substance of the frond, or inclosed within a hood having the same relation to the spores as an involucre to a seed-vessel). 113 Gen.; 1822 Sp.

Natural Orders.—15. Ricciaceae, or Crystalworts. 16. Marchantiaceae, or Liverworts. 17. Jungermanniaceae, or Scalemosses. 18. Equisetaceae, or Horsetails. 19. Andromedaceae, or Splitmosses. 20. Bryaceae, or Urnmosses.

5. **LYCOPODALES.**—Vascular. Spore-cases axillary or radical, one or many-celled. Spores of two sorts. 6 Gen.; 224 Sp.

Natural Orders.—21. Lycopodiaceae, or Clubmosses. 22. Marsileaceae, or Pepperworts.

6. **FILICALES.**—Vascular. Spore-cases marginal or dorsal, one-celled, usually surrounded by an elastic ring. Spores of but one sort. 192 Gen.; 2040 Sp.

Natural Orders.—23. Ophioglossaceae, or Adders' Tongues. 24. Polypodiaceae, or Ferns. 25. Danaceae, or Danesads.

CLASS III.—RHIZOGENS.—21 Genera; 53 Species.

ALLIANCE THE SAME AS THE CLASS.

Natural Orders.—26. Balanophoraceae, or Cynomoriums. 27. Cyttinaceae, or Cistustrapes. 28. Rafflesiaceae, or Rafflesiads.

CLASS IV.—ENDOGENS.—1420 Genera; 13684 Species.

ALLIANCES OF ENDOGENS.

- * *Flowers glumaceous* (that is to say, composed of bracts not collected in true whorls, but consisting of imbricated colourless or herbaceous scales).

7. **GLUMALES.** 439 Gen.; 6186 Sp.

Natural Orders.—29. Graminaceae, or Grasses. 30. Cyperaceae, or Sedges. 31. Desvaxiaceae, or Bristleworts. 32. Restiaceae, or Restiads. 33. Eriocaulaceae, or Pipeworts.

- ** *Flowers petaloid, or furnished with a true calyx or corolla, or with both, or absolutely naked; ♂ ♀ (that is, having sexes altogether in different flowers, without half-formed rudiments of the absent sexes being present).**

* The following signs are employed in this scheme:—

♂ Signifies a bisexual, or hermaphrodite plant.

♀ An unisexual, or male plant.

♂ An unisexual, or female plant.

Flowers having two coverings, as calyx and corolla, are said to be *Didclamydeous*; and one covering, *Monoclamydeous*. If they vary so that some have one and others two coverings, they are called *Monodidclamydeous*.

8. **ARALES**.—Flowers naked, or consisting of scales, 2 or 3 together, or numerous, and then sessile on a simple naked spadix; embryo axile; albumen mealy or fleshy. (Some have no albumen.) 41 *Gen.*; 278 *Sp.*

Natural Orders.—34. Pistiaceæ, or Lemnads, or Duckweeds. 35. Typhaceæ, or Typhads, or Bulrushes. 36. Araceæ, or Arada. 37. Pandanaceæ, or Screw-pines.

9. **PALMALES**.—Flowers perfect (with both calyx and corolla), sessile on a branched scaly spadix; embryo vague, solid; albumen horny or fleshy. Some Palms are ♀. 73 *Gen.*; 400 *Sp.*

Natural Orders.—38. Palmaceæ, or Palms.

10. **HYDRALES**.—Flowers perfect or imperfect, usually scattered; embryo axile, without albumen—aquatics. (Some are ♂.) 26 *Gen.*; 48 *Sp.*

Natural Orders.—39. Hydrocharidaceæ, or Hydrocharads. 40. Naiadaceæ, or Naiads. 40. *bis*. Triuridaceæ, or Triurids. 41. Zosteraceæ, or Seawracks.

•• Flowers furnished with a true calyx and corolla, adherent to the ovary; ♀.

11. **NARCISSALES**.—Flowers symmetrical; stamens 3 or 6, or more, all perfect; seeds with albumen. (Some Bromeliaceæ have a free calyx and corolla.) 163 *Gen.*; 1238 *Sp.*

Natural Orders.—42. Bromeliaceæ, or Bromeliads. 43. Taccaceæ, or Taccads. 44. Hæmodoraceæ, or Bloodroots. 45. Hypoxidaceæ, or Hypoxids. 46. Amaryllidaceæ, or Amaryllids. 47. Iridaceæ, or Irids.

12. **AMOMALES**.—Flowers unsymmetrical; stamens 1 to 5, some at least of which are petaloid; seeds with albumen. 39 *Gen.*; 427 *Sp.*

Natural Orders.—48. Musaceæ, or Musads. 49. Zingiberaceæ, or Gingerworts. 50. Marantaceæ, or Marants.

13. **ORCHIDALES**.—Flowers unsymmetrical; stamens 1 to 3; seeds without albumen. 404 *Gen.*; 3035 *Sp.*

Natural Orders.—51. Burmanniaceæ, or Burmanniads. 52. Orchidaceæ, or Orchids. 53. Apostasiaceæ, or Apostasiads.

•• Flowers furnished with a true calyx and corolla, free from the ovary; ♀.

14. **XTRIDALES**.—Flowers half herbaceous, 2-3-petaloidous; albumen copious. 24 *Gen.*; 336 *Sp.*

Natural Orders.—54. Philodracæ, or Waterworts. 55. Xyridaceæ, or Xyrids. 56. Comelynacæ, or Spiderworts. 57. Mayaceæ, or Mayacs.

15. **JUNCALIS**.—Flowers herbaceous, dry, and permanent, scarious if coloured; albumen copious. (Some Callas have no albumen.) 27 *Gen.*; 260 *Sp.*

Natural Orders.—58. Juncaceæ, or Rushes. 59. Orontiaceæ, or Orontiads.

16. **LILIALES**.—Flowers hexapetaloidous, succulent, and withering; albumen copious. 171 *Gen.*; 1365 *Sp.*

Natural Orders.—60. Gilliesiaceæ, or Gilliesiads. 61. Melanthaceæ, or Melanths. 62. Liliaceæ, or Lilyworts. 63. Pontederaceæ, or Pontederads.

17. **ALISMALIS**.—Flowers 3-6-petaloidous, apocarpal; albumen none. (Some Alismads are absolutely ♂.) 14 *Gen.*; 101 *Sp.*

Natural Orders.—64. Butomaceæ, or Butomads. 65. Alismaceæ, or Alismads. 66. Juncaceæ, or Arrow-grasses.

CLASS V.—DICTYOGENS.—17 Genera; 268 Species.

Natural Orders.—68. Dioscoreaceæ, or Yams. 69. Smilacæ, or Sarsaparillas. 70. Philesiaceæ, or Philesiads. 71. Trilliaceæ, or Parids. 72. Roxburghiaceæ, or Roxburghworts.

CLASS VI.—GYMNOGENS.—37 *Genera*; 210 *Species*.

Natural Orders.—73. Cycadeaceæ, or Cycads. 74. Pinaceæ, or Conifers. 75. Taxaceæ, or Taxads. 76. Gnetaceæ, or Joint Firs.

CLASS VII.—EXOGENS.—6191 *Genera*; 66225 *Species*.

ALLIANCES OF EXOGENS.

SUB-CLASS I.—DICLINOUS EXOGENS.

Flowers ♂ ♀, without any customary tendency to ♂.

18. AMENITALES.—Flowers in catkins, achlamydeous or monochlamydeous; carpels superior; embryo small, with little or no albumen. 13 *Gen.*; 358 *Sp.*

Natural Orders.—77. Casuarinaceæ, or Beefwoods. 78. Betulaceæ, or Birchworts. 79. Altingiaceæ, or Liquidambars. 80. Salicaceæ, or Willowworts. 81. Myricaceæ, or Galeworts. 82. Elæagnaceæ, or Oleasters.

19. URTICALES.—Flowers scattered, monochlamydeous; carpel single, superior; embryo large, lying in a small quantity of albumen. 61 *Gen.*; 572 *Sp.*

Natural Orders.—83. Stilaginaceæ, or Antidesmads. 84. Urticaceæ, or Nettleworts. 85. Ceratophyllaceæ, or Hornworts. 86. Cannabinaceæ, or Hempworts. 87. Moraceæ, or Morads. 88. Artocarpaceæ, or Artocarpads. 89. Platanaceæ, or Planes.

20. EUPHORBIALES.—Flowers scattered, monodichlamydeous; carpels consolidated, superior; placentæ axile, in a large quantity of abundant albumen. (Albumen occasionally absent). 203 *Gen.*; 2527 *Sp.*

Natural Orders.—90. Euphorbiaceæ, or Spurgeworts. * Gyrostemonæ. 91. Scepacæ, or Scepad. 92. Callitrichaceæ, or Starworts. 93. Empetraceæ, or Crowberries. * Batidæ. 94. † Nepenthaceæ, or Nepenths.

21. QUERNALES.—Flowers in catkins, monochlamydeous; carpels inferior; embryo amygdaloid, without albumen. 12 *Gen.*; 292 *Sp.*

Natural Orders.—95. Corylaceæ, or Mastworts. 96. Juglandaceæ, or Juglands.

22. GARRYALES.—Flowers monochlamydeous, sometimes amentaceous; carpels inferior; embryo minute, in a large quantity of albumen. 3 *Gen.*; 7 *Sp.*

Natural Orders.—97. Garryaceæ, or Garryads. 98. Helwingiaceæ, or Helwingians.

23. MENISPERMALES.—Flowers monodichlamydeous; carpels superior, disunited; embryo surrounded by abundant albumen. 39 *Gen.*; 281 *Sp.*

Natural Orders.—99. Monimiaceæ, or Monimiads. 100. Atherospermaceæ, or Plume-Nutmegs. 101. Myristicaceæ, or Nutmegs. 102. Lardizabalaceæ, or Lardizabalads. 103. Schizandraceæ, or Kadsurads. 104. Menispermaceæ, or Menispermads.

24. CUCURBITALES.—Flowers monodichlamydeous; carpels inferior; placentæ parietal; embryo without albumen. 61 *Gen.*; 433 *Sp.*

Natural Orders.—105. Cucurbitaceæ, or Cucurbits. 106. Datisceæ, or Datiscads. 107. Begoniaceæ, or Begoniads.

25. PAPAYALES.—Flowers dichlamydeous; carpels superior, consolidated; placentæ parietal; embryo surrounded by abundant albumen. 11 *Gen.*; 29 *Sp.*

Natural Orders.—108. Papayaceæ, or Papayads. 109. Pangiacæ, or Panglads.

SUB-CLASS II.—HYPOGINOUS EXOGENS.

Flowers $\bar{\gamma}$, or $\delta \bar{\gamma} \bar{\gamma}$; stamens entirely free from the calyx and corolla.

26. **VIOLALES**.—Flowers monodichlamydeous; placentæ parietal or sutural; embryo straight, with little or no albumen. 98 Gen.; 1282 Sp.

Natural Orders.—110. Flacourtiaceæ, or Bixads. 111. Lacisternaceæ, or Lacisternads. 112. Samydeæ, or Samyds. 113. Passifloraceæ, or Passionworts. 114. Malesherbiaceæ, or Crownworts. 115. Moringaceæ, or Moringads. 116. Violaceæ, or Violetworts. 117. Frankeniaceæ, or Frankeniads. 118. Tamaricaceæ, or Tamarisks. 119. Sauvagesiaceæ, or Sauvageads. 120. Crassulaceæ, or Houseleeks. 121. Turneraceæ, or Turnersads.

27. **CISTALES**.—Flowers monodichlamydeous; placentæ parietal or sutural; embryo curved or spiral; with little or no albumen. 214 Gen.; 2166 Sp.

Natural Orders.—122. Cistaceæ, or Rock Roses. 123. Brassicaceæ, or Crucifers. 124. Resedaceæ, or Weldworts. 125. Capparidaceæ, or Capparids.

28. **MALVALES**.—Flowers monodichlamydeous; placentæ axile; calyx valvate in æstivation; corolla imbricated or twisted; stamens definite or 00; embryo with little or no albumen. 160 Gen.; 1933 Sp.

Natural Orders.—126. Sterculiaceæ, or Sterculiads. 127. Byttneriaceæ, or Byttneriads. 128. Vivianiaceæ, or Vivianiads. 129. Tropæolaceæ, or Indian Crosses. 130. Malvaceæ, or Mallowworts. 131. Tiliaceæ, or Lindenblooms.

29. **SAPINDALES**.—Flowers monodichlamydeous, unsymmetrical; placentæ axile; calyx and corolla imbricated; stamens definite; embryo with little or no albumen. (Stamens rarely 00.) 132 Gen.; 1656 Sp.

Natural Orders.—132. Tremendraceæ, or Poreworts. 133. Polygalaceæ, or Milkworts. 134. Vochysiaceæ, or Vochyads. 135. Staphyleaceæ, or Bladder Nuts. 136. Sapindaceæ, or Soapworts. 137. Petiveriaceæ, or Petiveriads. 138. Aceraceæ, or Maples. 139. Malpighiaceæ, or Malpighiads. 140. Erythroxylaceæ, or Erythroxyls.

30. **GUTTIFERALS**.—Flowers monodichlamydeous; placentæ axile; calyx imbricated; corolla imbricated or twisted; stamens 00; embryo with little or no albumen. (Stamens sometimes definite in number.) 93 Gen.; 642 Sp.

Natural Orders.—141. Dipteraceæ, or Dipterads. 142. Ternströmiaceæ, or Theads. 143. Rhizobolaceæ, or Rhizobols. 144. Clusiaceæ, or Guttifers. 145. Marcgraviaceæ, or Marcgraviads. 146. Hypericaceæ, or Tutsans. 147. Reaumuriaceæ, or Reaumuriads.

31. **NYMPHEALES**.—Flowers dichlamydeous; placentæ axile or sutural; stamens 00; embryo on the outside of a very large quantity of mealy albumen. (A part have no albumen.) 8 Gen.; 56 Sp.

Natural Orders.—148. Nymphaeaceæ, or Water-lilies. 149. Cabombaceæ, or Water-shields. 150. Nelumbiaceæ, or Waterbeans.

32. **RAVALES**.—Flowers monodichlamydeous; placentæ sutural or axile; stamens 00; embryo minute, inclosed in a large quantity of fleshy or horny albumen. 119 Gen.; 1703 Sp.

Natural Orders.—151. Magnoliaceæ, or Magnoliads. 152. Anonaceæ, or Anonads. 153. Dilleniaceæ, or Dilleniads. 154. Ranunculaceæ, or Crowfoots. 155. Sarraceniaceæ, or Sarraceniads. 156. Papaveraceæ, or Poppyworts.

33. **BERBERALES**.—Flowers monodichlamydeous, unsymmetrical in the ovary; placentæ sutural, parietal, or axile; stamens definite; embryo inclosed in a large quantity of fleshy albumen. 79 Gen.; 604 Sp.

Natural Orders.—157. Droseraceæ, or Sundews. 158. Fumariaceæ, or Fumeworts. 159. Berberidaceæ, or Berberids. 160. Vitaceæ, or Vineworts. 161. Pittosporaceæ, or Pittosporads. 162. Olacaceæ, or Olacads. 163. Cyrillaceæ, or Cyrillads.

34. **ERICALES**.—Flowers dichlamydeous, symmetrical in the ovary; placentæ axile; stamens definite; embryo inclosed in a large quantity of fleshy albumen. (Stamens occasionally adherent to the corolla.) 89 Gen.; 1215 Sp.

Natural Orders.—164. Humiriaceæ, or Humiriads. 165. Epacridaceæ, or Epacrids. 166. Pyrolaceæ, or Winter-greens. 167. Francoaceæ, or Francoads. 168. Menotropaceæ, or Fir-rapes. 169. Ericaceæ, or Heathworts.

35. **RUTALES.**—Flowers monodichlamydeous, symmetrical; placenta axile; calyx and corolla imbricated, if present; stamens definite; embryo with little or no albumen. (Occasionally ♂ ♀). 236 *Gen.*; 1233 *Sp.*

Natural Orders.—170. Aurantiacæ, or Citronworts. 171. Amyridacæ, or Amyrids. 172. Cedrelacæ, or Cedrelads. 173. Meliacæ, or Meliads. 174. Anacardiaceæ, or Anacards, or Terebinths. 175. Connaracæ, or Connarads. 176. Rutacæ, or Rueworts. 177. Xanthoxylacæ, or Xanthoxyls. 178. Ochnacæ, or Ochnads. 179. Simarubacæ, or Quassads. 180. Zygophyllacæ, or Bean-capers. 181. Elatinacæ, or Water-peppers. 182. Podostemacæ, or Podostemads.

36. **GERANIALES.**—Flowers monodichlamydeous, symmetrical; placenta axile; calyx imbricated; corolla twisted; stamens definite; embryo with little or no albumen. 19 *Gen.*; 1033 *Sp.*

Natural Orders.—183. Limacæ, or Flaxworts. 184. Chlénacæ, or Chlénads. 185. Oxalidacæ, or Oxalids. 186. Balsaminacæ, or Balsams. 187. Geraniacæ, or Cranesbills.

37. **SILENALES.**—Flowers monodichlamydeous; placenta free, central; embryo external, curved round a little mealy albumen; carpels more than one, completely combined into a compound fruit. (Some slightly perigynous, others ♂ ♀.) 118 *Gen.*; 1829 *Sp.*

Natural Orders.—188. Caryophyllacæ, or Silenads. 189. Illecebracæ, or Knotworts. 190. Portulacæ, or Purslanes. 191. Polygonacæ, or Buckwheats.

38. **CHENOPODALES.**—Flowers monochlamydeous; placenta free, central; embryo external, either curved round or applied to the surface of a little mealy or horny albumen; carpels solitary, or if more than one, distinct. (Some slightly perigynous, others ♂ ♀). 125 *Gen.*; 803 *Sp.*

Natural Orders.—192. Nyctaginacæ, or Nyctagoes. 193. Phytolaccacæ, or Phytolaccads. 194. Amarantacæ, or Amaranths. 195. Chenopodiaceæ, or Chenopods.

39. **PIPERALES.**—Flowers achlamydeous; embryo minute, on the outside of a large quantity of mealy albumen. (Occasionally ♂ ♀). 27 *Gen.*; 622 *Sp.*

Natural Orders.—196. Piperacæ, or Pepperworts. 197. Chloranthacæ, or Chloranths. 198. Saururacæ, or Saururads.

SUB-CLASS III.—PERIGYNOUS EXOGENS.

Flowers ♂, or ♂ ♀ ♀; stamens growing to the side of either the calyx or the corolla; ovary superior, or nearly so.

40. **FICOIDALES.**—Flowers monodichlamydeous; placenta central or axile; corolla, if present, polypetalous; embryo external, and curved round a small quantity of mealy albumen. 24 *Gen.*; 468 *Sp.*

Natural Orders.—199. Basellacæ, or Basellads. 200. Mesembryacæ, or Ficoids. 201. Tetragoniaceæ, or Aizoons. 202. Scleranthacæ, or Scleranthads.

41. **DAPHNALES.**—Flowers monochlamydeous; carpel solitary; embryo amygdaloid, without albumen. 129 *Gen.*; 1406 *Sp.*

Natural Orders.—203. Thymelacæ, or Daphnads. 204. Proteacæ, or Proteads. 205. Lauracæ, or Laurels. 206. Cassythnacæ, or Dodder-laurels.

42. **ROSALES.**—Flowers monodichlamydeous; carpels more or less distinct; placenta sutural; seeds definite; corolla, if present, polypetalous; embryo amygdaloid, with little or no albumen. 551 *Gen.*; 1491 *Sp.*

Natural Orders.—207. Calycanthacæ, or Calycanths. 208. Chrysobalanacæ, or Chrysobalanans. 209. Fabacæ, or Leguminous plants. 210. Drupacæ, or Almondworts. 211. Pomacæ, or Appleworts. 212. Sanguisorbacæ, or Sanguisorbs. 213. Rosacæ, or Roseworts.

43. **SAXIFRAGALES.**—Flowers monodichlamydeous; carpels consolidated; placenta sutural or axile; seeds 60; corolla, if present, polypetalous; embryo taper, with a long radicle, and a little or no albumen. 89 *Gen.*; 761 *Sp.*

Natural Orders.—214. Saxifragacæ, or Saxifrages. 215. Hydrangeacæ, or Hydrangeads. 216. Cunoniaceæ, or Cunoniads. 217. Brexiacæ, or Brexiads. 218. Lythracæ, or Rosetrifées.

44. RHAMNALES.—Flowers monodichlamydeous; carpels consolidated; placentæ axile; fruit capsular, berried, or drupaceous; seeds definite; embryo amygdaloid, with little or no albumen. 123 Gen.; 1034 Sp.

Natural Orders.—219. Pennaceæ, or Sarcocollads. 220. Aquillariaceæ, or Aquillariads. 221. Ulmaceæ, or Elmworks. 222. Rhamnaceæ, or Rhamnads. 223. Chailletiacæ, or Chailletlads. 224. Hippocrateaceæ, or Hippocrateads. 225. Celastraceæ, or Spindle-trees. 226. Stackhouseiaceæ, or Stackhouseiads. 227. Sapotaceæ, or Sapotads. 228. Styracaceæ, or Storarworks.

45. GENTIANALES.—Flowers dichlamydeous, monopetalous; placentæ exile or parietal; embryo minute, or with the cotyledons much smaller than the radicle, lying in a large quantity of albumen. 221 Gen.; 1580 Sp.

Natural Orders.—229. Ebenaceæ, or Ebanads. 230. Aquifoliaceæ, or Hollyworks. 231. Apocynaceæ, or Dogbanes. 232. Loganiaceæ, or Legoniads. 233. Diapensiaceæ, or Diapensiads. 234. Stilbaceæ, or Stilbids. 235. Orobanchaceæ, or Broomrape. 236. Gentianaceæ, or Gentianworks.

46. SOLANALES.—Flowers dichlamydeous, monopetalous, symmetrical; placentæ axile; fruit 2-3-celled; embryo large, lying in a small quantity of albumen. (Occasionally achlamydeous or polypetalous). 298 Gen.; 2934 Sp.

Natural Orders.—237. Oleaceæ, or Oliveworks. 238. Solanaceæ, or Nightshades. 239. Asclepiadaceæ, or Asclepiads. 240. Cordiaceæ, or Sebestens. 241. Convolvulaceæ, or Bindweeds. 242. Cuscutaceæ, or Dodders. 243. Polemoniaceæ, or Phloxworks.

47. CORTUSALES.—Flowers dichlamydeous, monopetalous, symmetrical; placentæ free, central; embryo lying among a large quantity of albumen. (Occasionally monochlamydeous, or polypetalous). 86 Gen.; 880 Sp.

Natural Orders.—244. Hydrophyllaceæ, or Hydrophyls. 245. Plumbaginaceæ, or Leadworks. 246. Plantaginaceæ, or Ribworks. 247. Primulaceæ, or Primworks. 248. Myriniaceæ, or Ardisiads.

48. ECHIALES.—Flowers dichlamydeous, monopetalous, symmetrical, or unsymmetrical; fruit nucamentaceous, consisting of several one-seeded nuts, or of clusters of them, separate or separable; embryo large, with little or no albumen. (Very rarely hypogynous!) 280 Gen.; 4158 Sp.

Natural Orders.—249. Jasmynaceæ, or Jasmynworks. 250. Salvadoraceæ, or Salvadorads. 251. Ehretiaceæ, or Ehretlads. 252. Nolanaceæ, or Nolanads. 253. Boraginaceæ, or Borageworks. 254. Brunoniaceæ, or Brunoniads. 255. Lamiaceæ, or Labiates. 256. Verbenaceæ, or Verbenes. 257. Myoporaceæ, or Myoporads. 258. Selaginaceæ, or Selagids.

49. BIGNONIALES.—Flowers dichlamydeous, monopetalous, unsymmetrical; fruit capsular or berried, with its carpels quite consolidated; placentæ axile, or parietal, or free central; embryo with little or no albumen. 408 Gen.; 3508 Sp.

Natural Orders.—259. Pedaliaceæ, or Pedaliads. 260. Gesneraceæ, or Gesnerworks. 261. Crescentiaceæ, or Crescentiads. 262. Bignoniaceæ, or Bignoniads. 263. Acanthaceæ, or Acanthads. 264. Scrophulariaceæ, or Linariads. 265. Lentibulariaceæ, or Butterworks.

SUB-CLASS IV.—EPIGYNOUS EXOGENS.

Flowers ♀, or ♂ ♀ ♀: stamens growing to the side of either the calyx or corolla; ovary inferior, or nearly so.

50. CAMPANALES.—Flowers dichlamydeous, monopetalous; embryo with little or no albumen. 1102 Gen.; 10491 Sp.

Natural Orders.—266. Campanulaceæ, or Bellworks. 267. Lobeliaceæ, or Lobelliads. 268. Goodeniaceæ, or Goodeniads. 269. Stylidiaceæ, or Styleworks. 270. Valerianaceæ, or Valerianworks. 271. Dipsacaceæ, or Teazleworks. 272. Calyceraceæ, or Calycers. 273. Asteraceæ, or Composites.

51. MYRTALES.—Flowers dichlamydeous, polypetalous; placentæ axile; embryo with little or no albumen. (Occasionally monochlamydeous). 253 Gen.; 3340 Sp.

Natural Orders.—274. Combretaceæ, or Myrobalans. 275. Alangiaceæ, or Alangiads. 276. Chamelauciaceæ, or Fringe Myrtles. 277. Haloragaceæ, or Hippurids. 278. Onagraceæ, or Onagrats. 279. Rhizophoraceæ, or Mangroves. 280. Belvisiaceæ, or Napoleonworks. 281. Melastomaceæ, or Melastomads. 282. Myrtaceæ, or Myrtleblooms. 283. Lecythidaceæ, or Lecyths.

52. **CACTALES**.—Flowers dichlamydeous, polypetalous; placentæ parietal; embryo with little or no albumen. 39 *Gen.*; 900 *Sp.*
Natural Orders.—284. Homaliaceæ, or Homaliads. 285. Loasaceæ, or Loasads. 286. Cactaceæ, or Indian Figs.
53. **GROSSALES**.—Flowers dichlamydeous, polypetalous; seeds numerous, minute; embryo small, lying in a large quantity of albumen. 22 *Gen.*; 208 *Sp.*
Natural Orders.—287. Grossulariaceæ, or Currantworts. 288. Escalloniaceæ, or Escalloniads. 289. Philadelphaceæ, or Syringas. 290. Barringtoniaceæ, or Barringtoniads.
54. **CINCHONALES**.—Flowers dichlamydeous, monopetalous; embryo minute, lying in a large quantity of albumen. 305 *Gen.*; 3243 *Sp.*
Natural Orders.—291. Vacciniaceæ, or Cranberries. 292. Columelliaceæ, or Columelliads. 293. Cinchonaceæ, or Cinchonads. 294. Caprifoliaceæ, or Caprifolls. 295. Galiaceæ, or Stellates.
55. **UMBELLALES**.—Flowers dichlamydeous, polypetalous; seeds solitary, large; embryo small, lying in a large quantity of albumen. 322 *Gen.*; 1780 *Sp.*
Natural Orders.—296. Apiaceæ, or Umbellifers. 297. Araliaceæ, or Ivyworts. 298. Cornaceæ, or Cornels. 299. Hamamelidaceæ, or Witch-Hazels. 300. Bruniaceæ, or Bruniads.
56. **ASARALES**.—Flowers monochlamydeous; embryo small, lying in a large quantity of albumen. 49 *Gen.*; 652 *Sp.*
Natural Orders.—301. Santalaceæ, or Sandalworts. 302. Loranthaceæ, or Loranths. 303. Aristolochiaceæ, or Birthworts.

Had our space permitted, we should now proceed to consider the various alliances and natural orders in detail, so as to lay before our readers a complete account of the whole kingdom of plants; but we must content ourselves with the extended scheme which we have now inserted.

We have but little to add to the directions which we gave for the prosecution of the study of classification under the Linnæan system; but it is important to bear in mind, that under the natural arrangement the stamens and pistils play a subordinate part, and are only accounted as a portion of the whole constitution of the plant. But very minute and constant attention is directed to the ovule and the seed; so that a pocket magnifier of moderate power is at all times necessary.

EDWARD SMITH, M.D.



CRESTED HERON.



GREY BABOON.

ON THE STUDY OF ANIMALS.

IN whatever direction we turn our eyes, we everywhere meet the varied forms of animal life. Earth, air, water, are all alike occupied by multitudes of living creatures, each fitted especially for the habitation assigned to it by nature. Every wood or meadow—nay, every tree or shrub, or tuft of grass,—has its inhabitants; even beneath the surface of the ground numbers of animals may be found fulfilling the purposes for which their species were called into existence. Myriads of birds dash through the air, supported on their feathered pinions, or solicit our attention by the charming song which they pour forth from their resting places; whilst swarms of insects, with still lighter wings, dispute with them the empire of the air. The waters, whether salt or fresh, are also filled with living organisms; fishes of many forms and varied colours, and creatures of still more strange appearance, swim silently through their depths, and their shores are covered with a profusion of polypes, sponges, starfishes, and other animals.

To whatever elevation we attain on the mountain sides, to whatever depth in the ocean we may sink the lead, everywhere shall we find traces of animal existence, everywhere find ourselves surrounded by living creatures, in a profusion and variety which may well excite our wonder and admiration.

Nor are these phenomena confined to any one region of the earth; on the contrary, the diversity of climate only adds to the variety of objects which the zoologist is called upon to contemplate. Thus the bold voyager of the inclement regions of the north, in losing sight of those productions of nature which met his eyes at home, finds, as it were, a new creation in his new abode—seals, by the hundred, basking in the scanty rays of the Arctic sun, or diving into the deep waters in search of their finny prey—the whale, rolling his vast bulk in the waves, and ever and anon driving high into the air his curious fountain—water, be it remembered, strained from the myriads of small animals which constitute the food of the leviathan. The air is peopled by innumerable

flights of marine birds; the sea by still more countless swarms of fishes; and the land affords a habitation to the elk and the reindeer, the arctic fox, and other creatures peculiar to these regions.

If we turn our regards southwards, to the tropical regions of the earth, the abundance and variety of animated beings increases more and more. Here the colossal elephant, and the equally unwieldy rhinoceros, crash through primeval forests; the lion and the tiger, and other predatory beasts, prowl through the thickets, seeking for their prey; on vast plains, countless herds of antelopes browse in fancied security, or dash swiftly away at the approach of danger; gigantic snakes lie coiled in horrid folds amongst the bushes, or hanging from the trees await their victims. The air and trees swarm with birds of gorgeous plumage, and insects of strange forms and brilliant colours. Nor are the waters less bountifully provided with inhabitants: every form with which we are acquainted in our own seas is here represented, but with still greater profusion and variety.

At night the ocean sparkles with a brilliancy which rivals the splendour even of a tropical sky; and this phenomenon, which may be witnessed, although in an inferior degree, in more temperate climes, is due to the presence of vast multitudes of minute phosphorescent animals, whose very existence would frequently remain unknown but for their powers of illuminating the waves by night.

And when we have exhausted the study of external nature, there is yet another world to which we may turn. Within our bodies, and those of every species of animal from the highest to nearly the very lowest, exist various forms of parasites, preying upon our substance or our food: creatures whose very existence and development are a mystery—a mystery, however, which, as far as it has yet been unravelled, serves to raise our expectations as to what remains behind.

ON ZOOLOGICAL CLASSIFICATION.

When we consider the immense number of animals existing on the face of the earth, of which we have endeavoured, in the preceding section, to give some slight idea, we are soon convinced that an attempt to obtain a knowledge of each of them individually, and without any acquaintance with their mutual relationships, would be a perfectly hopeless task. We are, in fact, compelled to call in the aid of some system of classification, which, by bringing together those animals which most resemble each other, and characterizing them by some common point of structure, may enable us to form a sort of general idea of the whole, and to remember more readily the peculiarities of each. Some such classification, rough and imperfect it may be, is, indeed, formed by every observant mind; and its terms find a place in ordinary language. Beasts, birds, and fishes, reptiles, and insects, are words familiar to every one, and convey to the minds of those to whom they are addressed a more or less definite idea, according to the preconceived notions of the hearer.

Scientific zoological classification is, in point of fact, to a certain extent, coincident with this popular classification. The latter being the result of observation, the only foundation of natural history, must necessarily be more or less correct, according to the extent to which the different kinds of animals bring themselves under the notice of mankind; thus we find that tolerably clear notions exist as to the differences between a beast, a bird, and a fish,—these being creatures that pass constantly under our eyes; although, even with respect to these groups, we find some erroneous ideas to prevail.

But with respect to insects, and other lower animals with which mankind at large are not familiar, the classification of ordinary language is by no means so precise; so that whilst, in the former cases, zoology can adopt the popular groups merely by submitting them to a few modifications, in the latter, science is compelled to invent a system of her own.

This scientific classification is not, however, a mere arbitrary arrangement, like that of the words in a dictionary, with the sole object of enabling us to find out all that is known of a given animal in the shortest possible period of time,—it has another and a higher purpose in view, that of showing the mutual relations of the various members of the animal kingdom, and tracing, in a manner, the steps taken by the Creator in the modification of the same type to suit the various conditions in which His creatures were to be placed.

The knowledge of species constitutes the foundation of all zoological knowledge,—without which we can never arrive at sound generalisations. The *species*, which forms the first step in classification, consists of an assemblage of individual animals which are supposed all to have descended from the same parents, and exhibit the closest possible resemblance in all parts of their structure. This definition, if definition it may be called, must not, however, be taken in the strictest sense which might be applied to the words; for in many cases we find that individuals undoubtedly belonging to the same species vary considerably amongst themselves, principally in colour and size. Variation is generally to be observed, however, in animals under the influence of domestication, the individuals of most species of wild animals resembling each other so closely that it would be difficult to overlook their specific identity.

A test for the specific identity of animals, upon which much stress has been laid, is founded upon the supposed fact, that when two animals of different species breed together their offspring is always barren. This test is evidently applicable only when we can observe the animals alive; whilst, even under the most favourable circumstances, such observations would be very inconclusive, as hybrids, between undoubtedly distinct species, have been frequently known to breed.

We generally find that several species exhibit a considerable amount of resemblance one to another, agreeing perhaps in most points of importance, but differing in characters of minor value, such as colour, texture, and so forth. Such groups of species constitute the second upward step in classification—they are called *genera*. Thus the horse, the ass, and the zebra, although they may readily be distinguished from each other as species, present a very close resemblance in their general structure, and form a *genus*; the cat, the lion, the tiger, and the leopard are in the same case; as are also the dog, the wolf, the fox, and the jackal,—the animals may readily be distinguished as species, whilst the structure of their organs presents many common characters.

The arrangement of the species of animals in genera, gives rise to the modern system of zoological nomenclature. This system is called the *binomial system*, from the circumstance that, according to this method, every animal receives two names; one belonging to itself exclusively, the other in common with all the other species of the genus in which it is included. For example, the genus *Felis*, or cat, includes the lion, tiger, leopard, and cat, as species; they all accordingly bear the generic name *Felis*, with the addition of a second name specially applied to each, serving to distinguish it from all other species of the genus; thus the lion is called *Felis Leo*, the tiger *Felis Tigris*, the leopard *Felis Leopardus*, and the cat *Felis Cattus*. This method of nomenclature has at least this advantage over the plan of conferring only a single name upon each species that

when we hear for the first time the name of a newly discovered animal, if we are at all acquainted with the genus to which it belongs, the mere mention of the name puts us at once in possession of a considerable amount of information as to its structure, form, and habits. It was first adopted by the illustrious Linnæus, the modern founder of Natural History, in the tenth edition of his "*Systema Naturæ*," published in 1758.

Proceeding with our ascending scale of classification, we find that the genera in their turn are united by some common characters of importance into *families*, and these again into *tribes*. The tribes combine to form *orders*; in some cases we meet with intervening steps, uniting the tribes belonging to one order into two or three subordinate groups. The orders in their turn group themselves into *classes*; and these lead us up to certain primary divisions which, when put together, constitute the ANIMAL KINGDOM.

But although this be the means by which zoologists have arrived at certain conclusions as to classification, it is by no means necessary, nor indeed would it be convenient, to follow the same course in communicating those conclusions to the world; for this purpose we must commence at the opposite end of the scale—that is to say, with the largest groups.

We find, therefore, that all animals are formed upon certain plans or primary types, generally sufficiently distinct. But these primary types of animal structure present us each with well-marked subordinate types, in which, whilst the essential characters of the primary division are preserved, the general structure of the body undergoes more or less modification. These subordinate types become modified in their turn, so that we at last obtain a series of groups, each characterized by some peculiarity of structure, gradually diminishing in comprehensiveness from the animal kingdom to the species. The characters of the primary divisions of the animal kingdom we now proceed to investigate.

On the Primary Divisions of Animals.—At the lowest point of the animal kingdom, approaching so closely to the lowest forms of plants as sometimes to leave us almost in doubt to which of the great divisions of organized nature they should be referred, we meet with a series of creatures in which the functions of organic life are performed by its simplest element—the cell. From this circumstance they have received from naturalists the denomination of *unicellular animals*, or PROTOZOA.

These animals, in fact, consist entirely of elementary nucleated cells (see PHYSIOLOGY), or of aggregations of such cells, in which each still retains to a certain extent an existence independent of its fellows, and generally possesses the power, when separated from its attachments, not only of continuing its own life, but even of producing another compound structure similar to that from which it had been detached. These simple creatures possess no digestive cavity; their food, when solid, being received into the substance of the body, and there gradually assimilated. The nervous and vascular systems are equally deficient; in fact, the nucleus, which is an essential portion of the elementary cell, and one or more contractile vesicular spaces, are the only traces of internal organization observable in the clear gelatinous substance of which they are composed.

Reproduction is effected in general by the division of the substance of the animal; the phenomena of sexuality, which we shall meet with in all the higher animals, are here never witnessed.

From these simple creatures we pass to a group of animals, the lowest members of which exhibit but little, if any, advance in point of organization. They do not, it is true, consist of isolated cells, or of aggregations of similar independent cells; but in many instances their bodies and organs are constructed entirely of a gelatinous cellular

matter very like that of which the *Protozoa* are composed, and which appears to possess almost an equal power of retaining vitality in its smallest particles. As we advance in the group, however, we find the organization of its constituent animals growing more and more complicated, from the vital functions becoming more and more differentiated—that is to say, performed by organs specially devoted to each; until, from creatures roughly shaped out of a homogeneous semi-gelatinous mass, we gradually arrive at animals furnished with distinct nervous and vascular systems, organs of motion and reproduction.

The most striking character of the animals included in this group consists in the radiate arrangement of their organs (Fig. 1) round a central axis, which generally passes through the mouth. From this peculiarity they have been denominated by zoologists *radiated animals*: they constitute the division **RADIATA**. This group includes those



Fig. 1.—Star-fish.

animals which were formerly supposed to approach very closely to plants, or indeed rather to partake of a sort of mixed nature intermediate between animals and vegetables, hence called *zoophytes*, or animal-plants; and some authors make use of this name in preference to that of *Radiata*, to indicate the present group.

The nervous system can only be recognised distinctly in the most highly organized of these animals. In these it partakes of the radiate arrangement of the body (Fig. 2), the nerve distributed to each division of the body corresponding exactly with those of its neighbour, and arising from a separate centre. These centres are all placed in a circle round the mouth, and united by a cord which forms a complete ring.

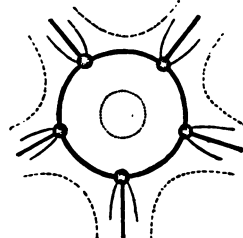


Fig. 2.—Nervous system of Star-fish.

The sense of touch appears to be the only one which can with certainty be ascribed to these animals; this resides in the general integument, and is also frequently exercised by special organs.

All the *Radiata* possess a mouth and intestinal cavity; but very few of them have a second opening for the discharge of faecal matters. They generally possess a more or less distinct vascular system; in some of the higher forms a sac-like heart occurs.

Sexual reproduction occurs in all the Radiata, and the sexes are generally on separate individuals. Propagation is also very commonly effected in this sub-kingdom by the formation of buds or gemmules; and these either remain attached to the parent stock, which thus goes on increasing continually in size, or become free, and lead an independent existence.

In the two preceding divisions of the animal kingdom we find the body formed upon two very different principles. In the first and lowest it may almost be said to be *amorphous*. The organs, such as they are, follow no particular arrangement; and in many cases it is impossible even to fix their relative position. In the second, however, a certain *symmetry* is observable; and this is the case also with the remaining groups, the characters of which we have yet to lay before the reader. But this symmetry is of a very different kind; in the *Radiata* the parts of the body are all grouped round a common axis, every organ being merely a repetition of its fellows; whilst in those which must now pass under consideration, the organs of the body are arranged more or less distinctly in pairs on each side of the body, so as to produce what has been termed by zoologists a *bilateral symmetry*. In none do we find this mode of construction so completely exhibited as in the animals forming the third primary division of the animal kingdom, to which we must now direct attention.

The most striking peculiarity of these animals, by which, in fact, they may generally



Fig. 3.—Centipede.

be distinguished at the first glance from all other creatures, is, that their bodies and limbs are composed more or less distinctly

of segments or rings. From this, which is their most prominent character, they have been denominated *articulated* or *annulose animals*. They constitute the division *ARTICULATA*.

The joints or segments of which their bodies are composed, are formed essentially by a series of transverse folds in the integument of the animal. In many of the lower forms the skin still remains perfectly soft and flexible; but in by far the greater number these folds become transformed into a series of horny or crustaceous rings (Fig. 3), united to each other by a softer portion of the integument, so as to permit a greater or less degree of flexibility. The limbs, as well as the body, are constructed of rings of various forms; and these, taken together may be regarded, to a certain extent, as a sort of *external skeleton*, fulfilling, as they do, most of the purposes of the skeleton in man, and the animals most related to him. Like this, it gives support to all the soft parts of the body, and furnishes points of attachment to the muscles; which again, by their action on the moveable pieces composing it, give rise to the various movements of the creature. In many cases all the segments composing the body, with the ex-



Fig. 4.—Crab (Thelphusa).

ception perhaps of those at the two extremities, are exactly similar; each presenting the same form and bearing the same organs as its neighbour. An instance of this may be seen in the Centipede, already figured; and it is still more strikingly exemplified in many marine worms. Generally, however, the segments present marked differences of form and comparative size, and in the structure of their appendages; this is very distinctly observable in the insects and crabs (Figs. 3, 4).

Every segment is supposed to be capable of bearing two pairs of appendages or members, one connected with the ventral, the other with the dorsal portion of the segment. Both pairs of members do in fact occur upon all, or a portion of the segments in some of these animals; but in general the ventral members alone are developed, and these only on certain segments. In the insects, in addition to three pairs of ventral members, or legs, we find generally two pairs of dorsal appendages—the wings. Sometimes, as in the earthworm and leech, the limbs are entirely deficient, or only represented by a few bristles; but, when present, their number is never less than six.

The nervous system of the *Articulata* generally exhibits the tendency to segmentary repetition, characteristic of the group, very distinctly. In

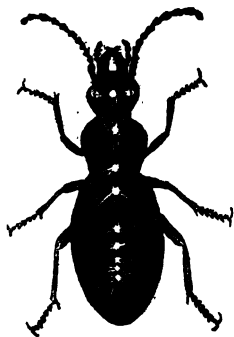


Fig. 5.—Nervous system of an insect.

its most characteristic form (Fig. 5), it consists of a double nervous cord running down the middle of the ventral portion of the body, and uniting a series of knots or ganglia which lie in its course; these ganglia give rise to nerves which are distributed to the various organs. The more elongated the body, and the more similar the different segments of which it is composed, the more regularly do the ganglia follow one another; whilst, when the segments become more or less amalgamated, the individual ganglia fuse in a corresponding degree into larger masses. This ventral cord originates from one or more cephalic ganglia of considerable size, situated in the head above the œsophagus, which give off two filaments to join the first ventral ganglion, and thus form a nervous ring surrounding the œsophagus. From this the ventral cord takes its rise.

In the lowest animals arranged in this division we have some difficulty in referring the nervous system to the articulate type; but when these animals present us with a distinct nervous system it consists of one or two ganglia situated in the neighbourhood of the œsophagus, and giving off two thin branches which run down the body.

The majority of the *Articulata* possess the senses in tolerable perfection. The eyes in many cases present a highly complex structure, consisting of a great number of hexagonal facets, each of which may be regarded as a distinct eye; this construction of the eyes is especially prevalent in insects, and is peculiar to the annulose division. When these eyes are wanting, and even when they are present, we frequently meet with simple eyes, which agree very closely in structure with the individual eyes, by the aggregation of which the compound visual organs are formed. The senses of hearing, taste, and smell, appear also to be possessed by a great many of these creatures; but the organs by which these faculties are exercised can seldom be indicated with any

degree of certainty. The sense of touch of course resides in the general integument; but special organs of touch are also frequently developed.

The mouth is nearly always furnished with several pairs of jaws, placed one behind the other, some serving for the prehension and others for the mastication of food. These jaws open laterally, so that the aperture of the mouth is *vertical*, or in the direction of the axis of the body.

Most of the *Articulata* have whitish or colourless blood. The only exceptions are to be met with amongst the worms, some of which have red blood. In these, however, the colour of the blood is inherent in the fluid portion, and not due to the presence of red corpuscles (see Physiology). Their circulation is effected by means of a *dorsal vessel*, which carries the blood from behind forwards; it returns to the posterior portion of the body, either through a proper vascular system, or by passing through interstices left in the tissues of the body.

Sexual oviparous reproduction prevails throughout this division. The sexes are generally separate, although in some of the lower forms we meet with complete hermaphroditism.

In the fourth great division of animals the bilateral type of structure is far from being so distinct as in the *Articulata*. It is, however, still to be recognized in the general arrangement of the external organs, especially of those surrounding the head.

These animals, of which the snail may be taken as a familiar example, are usually inclosed in a tough skin, to the inner surface of which the muscles are attached, and by its contraction and dilatation the movements of the animal are effected. With the exception of the cuttle fishes, in which a sort of cartilaginous support is present, none of these creatures possess anything which can be regarded as analogous to a skeleton; the body forms a soft mass, frequently varying greatly in form at the will of the creature. These peculiarities have led zoologists to give them the name of *molluscous*, or soft-bodied animals; they constitute the division *MOLLUSCA*.

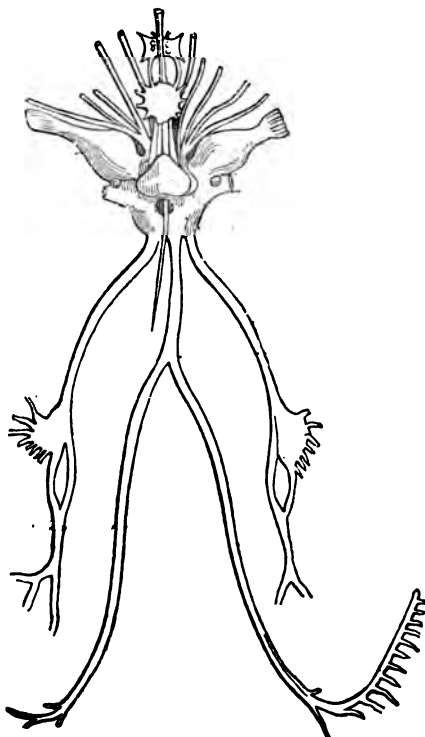


Fig. 6.—Nervous system of a *Sepia*.

In most of these animals the nervous system consists of a number of knots or ganglia, scattered more or less irregularly through the body, united with each other by nervous filaments, and giving off finer filaments, the true nerves, to the various organs.

In the more highly organized Mollusca three or four of these ganglia are collected in the head, forming a cephalic mass, which represents a brain (Fig. 6); but even in its most condensed form the separate cephalic ganglia may still be recognized, forming a sort of ring through which the œsophagus passes.

Some of the lower forms arranged with the molluscous animals by modern zoologists, possess only a single ganglion, from which filaments are given off in all directions; and between this and the highly complicated structure represented in Ffg. 6, we meet with every conceivable gradation.

As might be expected from the great differences displayed by the members of this great division of the animal kingdom, in regard to the degree of development of the nervous system, the senses are possessed by them in very various degrees of perfection. In some of the lowest forms the universal sense of touch appears to be the only one present; but as we ascend in the scale we meet with creatures more highly endowed in this respect. Tentacles, or special organs of touch, frequently occur, generally in the neighbourhood of the head; organs of sight, hearing, smell, and taste, make their appearance, until in the highest forms of molluscous animals we find the organs of the senses as highly developed as in many of those belonging to the highest division.

The skin of these animals generally lies loosely about the body, so as to form a sort of cloak or *mantle*. The mantle frequently possesses the power of secreting a hard substance, well known as the *shell*, which serves for the protection of the creature (Fig. 7). It increases with the growth of the animal, and varies in form according to the species which inhabits it.

The intestinal canal is very variable in its structure, but always presents two openings—a mouth and an anus; the liver frequently attains a very great degree of development.

The circulatory system is generally very highly organized; a heart, often divided into several compartments, with arteries and veins penetrating all parts of the body, existing in nearly all the Mollusca. The blood is colourless, or nearly so.

The Mollusca are oviparous animals; the male and female organs are frequently in separate individuals, although many species are hermaphrodite.

In the fifth and highest division of the animal kingdom we meet with a series of organs to which nothing similar occurs in the groups which have already passed under review.

All these animals possess a nervous system, consisting essentially of a brain, inclosed within a bony case, the skull, beneath which the œsophagus passes, and a single cord of nervous matter, originating from the lower part of the brain, passing through a large hole in the base of the skull, and running down through a bony canal, formed by the vertebral column, of which the skull is, in fact, only the anterior portion. As this set of organs, the brain and the spinal cord, the skull and the vertebral column, whilst possessed by no other animals, is constantly present in these, its existence will always



Fig. 7.—Pond Snail (*Lymnaea*).

serve to distinguish them from the rest of the animal kingdom. They are accordingly called *vertebrate animals*, and the division which they form, VERTEBRATA.

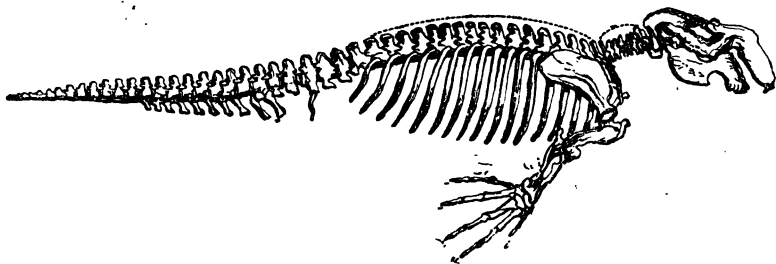


Fig. 8.—Skeleton of the Dugong.

These, however, are not the only characters possessed in common by vertebrate animals. The vertebral column forms only a portion of an internal bony framework or skeleton, which serves for the support of the soft portions of the body; and by furnishing the necessary points of attachment for the muscles, assists in effecting the movements of the animal. This framework generally consists of the *vertebral column*, including the *skull*; the *jaws*, which are regarded as appendages of the vertebrae, of which the skull is considered to be composed; the *ribs*, a series of bony arches, articulated at one extremity with the bones of the vertebral column, and at the other either attached to a central bony piece, the *sternum*, or lying perfectly free in the tissues of the body; and the *limbs*, which are never more than four in number. The jaws in these animals always separate in a vertical direction, so that the opening of the mouth is transverse. They all have red blood, and a muscular heart. Their reproduction is sexual, and the sexes are never united in the same individual.

The animals constructed upon this type are the most highly organized of living beings. In no others is the nervous matter, the seat of sensation, intelligence, and volition, presented in so concentrated a form—in none are the senses so perfect, or the various functions of the animal economy so completely isolated.

We thus see that animals are constructed upon five primary types or plans, of which all the varied forms presented by these creatures are but modifications, as though the Creator in designing the animal world had imposed upon himself, in the beginning, certain fixed rules, from which he would not swerve.

In this manner we get five groups, each of which leads us a step higher than the others; although it is by no means to be supposed that we have here that gradually ascending chain of beings so much talked of, in which every species, from the lowest to the highest, is supposed to form a link. It is merely in their most highly organized members that the mutual superiority or inferiority of these divisions can be recognized; and, as a general rule, it may be said, at all events for the Radiata, Articulata, and Mollusca, that the highest members of each group are considerably more perfectly organized than the lower members of the others. The Protozoa and Vertebrata appear to be exceptions to this rule; for the most highly organized of the former can scarcely

be regarded as superior even to the lowest forms of the other divisions; whilst the fishes, which constitute the lowest members of the vertebrate division, still appear to be more highly organized than the highest Mollusca.

These five divisions may therefore stand as follow :—

	V. VERTEBRATA.	
IV. MOLLUSCA.	III. ARTICULATA.	II. RADIATA.
	I. PROTOZOA.	

DIVISION I.—PROTOZOA.

General Characters.—This first division of the animal kingdom includes a number of creatures of a very low type of organization, which appear almost to occupy a sort of neutral ground between animals and vegetables.

The bodies of these animals consist either of a simple elementary cell, with its contents, or of an aggregation of several of these cells; each, however, still appearing to retain its independent existence. They are generally of very minute size, and only to be observed with the microscope.

It is in vain to seek in these creatures for any internal organs. They are entirely destitute of nervous and vascular systems; and the highest form of alimentary apparatus which is to be found in them consists only of a mouth and a short oesophagus. In many of them, however, no trace of any alimentary canal is to be discerned, and these either live by imbibing fluids through their outer surface, or by the amalgamation of solid substances with the gelatinous mass of which they are composed. This gelatinous matter, which has been termed *sarcode* by M. Dujardin, frequently has vacant spaces like small bladders in various parts of its substance: these appear and disappear according to circumstances or the will of the animal. They have, nevertheless, been mistaken by Ehrenberg and other observers for so many stomachs, although no one has ever attempted to prove the existence of an intestinal canal uniting them.

Almost all these creatures live in water: a few only inhabit the intestines of other animals. They generally present the appearance of a transparent gelatinous cell, in the midst of which a more or less distinct *nucleus* is to be observed. In addition to this nucleus, one or more clear pulsating spaces may be distinguished in the interior of the cells. These appear in some degree to effect a sort of circulation of the soft substance of the body, and may, therefore, be regarded as the first shadowing forth of a circulatory system. Many of them approach very closely in their structure to the germs given off by some of the lowest forms of aquatic plants, which, singularly enough, possess quite sufficient locomotive power to enable them to pass for animals when the observer is unable to trace their development; indeed, many of them have been described as belonging to the present group. It is very probable, in fact, that a great number of the creatures, still included in this division by naturalists, will prove, on further investigation, to be vegetable organisms.

The reproduction of these animals is generally effected by the division of the substance of the creature itself. In some instances two of them combine to form a single cell, which afterwards splits up to allow the escape of a number of young cells. The division always commences in the nucleus above-mentioned.

Some *Protozoa* are also propagated by the division of their substance in a different manner. A small bud shoots out from some portion of the body, which gradually

becomes developed until it resembles its parent, when it is usually cast off to shift for itself.

Many of these animals, simple as they may appear, have yet the faculty of producing a shelly covering for the support and protection of their gelatinous bodies; and these are not without their importance in the geological history of our planet. The chalk hills, whose cliffs are so characteristic of the south-eastern coast of this country, consist almost entirely of the shelly coats of innumerable multitudes of these minute creatures.

The sponges, perhaps the lowest forms in which animal existence is presented to our observation, are to be placed in this division, as they are also found to consist essentially of an aggregation of nucleated cells. It has often been considered doubtful whether these creatures are really animal organisms, as in many points, and especially in their mode of propagation, they very closely resemble the lowest forms of plants. Their true nature has long been a moot-point with naturalists; and by some zoologists they are altogether rejected from the animal kingdom, although the most recent researches, and especially those of M. Laurent, and of Mr. Carter, appear to establish their animal nature beyond a doubt.

Division.—The Protozoa are divided into three classes. In the first, to which the name of RHIZOPODA has been given, the body is composed entirely of the gelatinous matter above mentioned. The surface is not furnished with cilia, motion being effected by the extension of portions of the substance into filaments or processes of various forms. These creatures are either solitary or aggregated. In the latter case the compound animal is inclosed in a chambered shell, each individual cell-body occupying its own chamber.

The second class, including the sponges, consists entirely of associated cell animals; the individual cells resembling those of the preceding class in their power of extending the substance of their bodies in all directions; but in this class they are united by a mucilaginous intercellular substance, and supported upon a horny framework. From the masses formed by these creatures being perforated in every part with minute orifices, they have received the denomination of PORIFERA.

The animals constituting the third class of the Protozoa have been called INFUSORIA, from the circumstance that they were originally discovered in infusions of vegetable matter exposed to the air for a short time. They are generally solitary unicellular animals, and differ from the Rhizopoda in having the outer surface of the body of a somewhat firmer consistence than the rest of their substance. They are usually furnished with a mouth, and their movements are effected by means of cilia, or of one or more long filiform appendages attached to one extremity of the body.

CLASS I.—RHIZOPODA.

In the deposit formed at the bottom of fresh-water ponds, we may often meet with a singular minute gelatinous body, which constantly changes its form even under our eyes, and moves about in its native element by means of finger-like processes, which it appears to have the power of shooting out from any part of its substance. This shapeless gelatinous mass is an animal, the *Amœba diffluens* (Fig. 9), well known to microscopic observers under the name of the Proteus, from the continual changes of shape which it presents to our notice. It consists entirely of the granular gelatinous matter already mentioned as *sarcode*, and appears to be nearly homogeneous in its texture; that

is to say, the outer surface exhibits no signs of being bounded by any distinct membrane or layer of a firmer consistence than the rest of the body.

With the exception of the pulsating clear space, which has already been referred to as apparently constituting the first traces of a circulatory system, and the nucleus, which, as we have seen, is so essential a portion of the Protozoan animal, no indications of any internal organization are to be recognised in this creature; for it possesses neither mouth nor intestinal canal. It is not to be supposed, however, that the animal keeps a perpetual fast, or that its food is entirely of a fluid nature. On the contrary, it appears to be, in its small way, of an exceedingly voracious disposition, seizing upon any minute aquatic animals or plants that may come in its way, and appropriating them to the nutrition of its own gelatinous person.

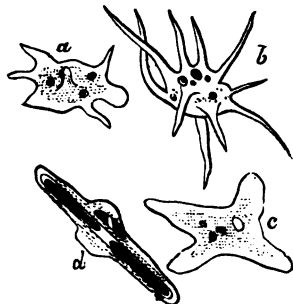


Fig. 9.—*Amoeba*, 380 diameters.

The mode in which this tender and apparently helpless creature effects this object is very remarkable. The gelatinous matter of which it is composed is capable, as we have seen, of extension in every direction; accordingly, when the *Amoeba* meets with anything that it regards as suitable for its support, the substance of the creature, as it were, grows round the object until this is completely inclosed within the body, when it is gradually dissolved. The substances swallowed, if such a term be admissible, by this hungry mass of jelly, are often so large, that the creature itself only seems to form a sort of gelatinous coat inclosing its prey; an instance of this is shown at *d* in the above figure.

This curious animal presents us with the essential characters of the class *Rhizopoda* in their simplest form. All the other members of the class resemble it in the texture of the body, and in the mode by which progression and nutrition are effected, however they may differ in other respects. In many cases, indeed in the majority, the creatures are inclosed in a shell or shield, from which the filamentous processes above described as the means by which motion is effected, are protruded through one or more holes pierced in the shell for this purpose. These processes themselves vary very considerably in form, being sometimes thick and finger-like, as in the *Amoeba*; in other instances thinner, variously branched, and often most intricately anastomosed.

The *Rhizopoda* are all aquatic animals. Some live in fresh water, but by far the greater number inhabit the sea. Although a few of them, like the *Amoeba*, are solitary, the class consists principally of associated animals; that is to say, of masses of individuals, forming, as it were, a common body, but each still retaining its independent existence.

This difference of habit affords us the means of dividing this class into two orders. The first, the *Monosomatia*, contains those *Rhizopoda* which only consist of a single animal; they are either entirely naked or inclosed in a capsule with a single opening for the extrusion of the motor filaments.

Of the naked forms, constituting the family *Proteida*, we have already had an example in the *Amoeba*; and the other members of the group present very similar characters.

The solitary *Rhizopoda*, furnished with a horny shell or capsule, forming a more or

less complete case for the animal, constitute the family *Arcellidae*. The filamentous processes by which motion is effected are protruded from a single aperture. These filaments are often much branched; they may be seen under the microscope gradually extending themselves, like streams of very soft gelatinous matter, which divide and subdivide in every direction. In the genus *Arcella*, from which the family derives its name, the shell is somewhat of a bell-shape, with a very large round opening. In *Englypha* it is of an oval or flask-like form, with the opening at the smaller end. In this genus the shell appears as though formed of a sort of mosaic of small horny pieces. In *Diffugia* (Fig. 10), the shell is often globular.

The animals constituting the second order, the *Polythalamia*, are all inclosed in calcareous shells. These creatures are social; the shells consisting of a series of distinct chambers, which sometimes communicate one with another, and sometimes appear to be completely closed up; each of them is supposed to contain a separate and probably independent animal. It is not improbable, however, that the individual animals may be so connected with each other, through the medium of the openings communicating between the cells, as to constitute a common mass, with which each animal is partially amalgamated.

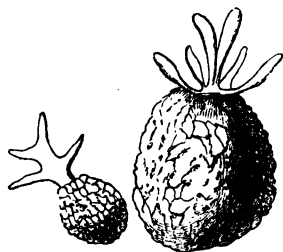


Fig. 10.—*Diffugia Globulosa*,
300 diameters.

In some instances each chamber of the common shell presents only a single external opening; but, as a general rule, the substance of the shell is pierced, like a sieve, with numerous minute pores, through which very delicate filaments are protruded.

All the *Polythalamia* inhabit the sea; and frequently occur in such great numbers that the fine calcareous sand which constitutes the sea-shore, in many places, consists almost entirely of their microscopic coats. At former periods of the earth's history they existed in even greater profusion than at present; and their fragile shells form the principal constituents of several very important geological formations. Thus the chalk appears to consist almost entirely of the shells of these animals, either in a perfect state, or worn and broken by the action of the waves; and they occur in great quantities in the marly and sandy strata of the tertiary epoch. The stone which is universally employed in Paris as a building stone is almost entirely composed of the fossil shells of an animal belonging to this order, the *Miliola*; so that this great city, of which its inhabitants used to say that he who had not seen Paris had seen nothing, owes its architectural beauties, at all events, to these minute creatures, of which many thousands would scarcely weigh an ounce. Lamarck, the great French naturalist, in referring to this circumstance, observes—"We scarcely condescend to examine microscopic shells, from their insignificant size; but we cease to think them insignificant when we reflect that it is by means of the smallest objects that nature everywhere produces her most remarkable and astonishing phenomena. Whatever she may seem to lose in point of volume, in the production of living bodies, is amply made up by the number of the individuals which she multiplies, with admirable promptitude, to infinity. The remains of such minute animals have contributed much more to the mass of materials which compose the exterior crust of the globe, than the bones of elephants, hippopotami, and whales."

From the extremely elegant structure of the shells of these animals, M. Alcide d'Orbigny, who was the first to call the attention of modern naturalists to them, was led to regard them as microscopic forms of Cephalopodous Mollusca, as they presented at first sight a considerable resemblance, on a small scale, to the chambered shells formed by many of those creatures. By M. d'Orbigny, and many subsequent naturalists, they were accordingly arranged in the class of *Cephalopoda*, with animals possessing at least as high a degree of organization as some of the lower Vertebrata; and it was not until the year 1835 that the researches of M. Dujardin—since amply confirmed by other observers—showed that the creatures to which these shells owed their construction were very nearly allied to the *Amœba*. Nearly two thousand species of these microscopic shells have been described; but it is probable that many of these will be found, on further investigation, to be only forms of the same animal in various stages of development. They have been divided into several families, characterized by the arrangement of the chambers constituting the shell.

In one, the *Stichostegidae*, the chambers are placed end to end in a row, so as to form a straight or but slightly curved shell (Fig. 11). In the second family, the *Enallostegidae*, the chambers are arranged alternately in two or three parallel lines; and as the construction of the shell is always commenced with a single small chamber, the whole necessarily acquires a more or less pyramidal form (Fig. 12). The third family, the *Helicostegidae*, presents us with some of the most beautiful forms that we meet with in these shells (Fig. 13). They commence by a small central chamber; and each of the sub-



Fig. 11. Nodosaria.

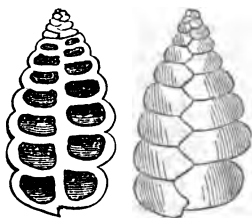


Fig. 12. Textularia.

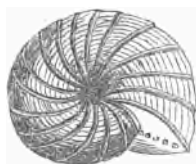


Fig. 13. Polystomella.

sequent chambers, which are arranged in a spiral form so as to give the entire shell much the aspect of a minute flattened snail, is larger than the one preceding it. It is in this family that we find the nearest approach, in external form, to the large chambered shells of the Cephalopodous Mollusca, of which the Nautilus and the Argonaut are examples. The fourth family, the *Entomostegidae*, stand in the same relation to the preceding, as the *Enallostegidae* to the *Stichostegidae*; that is to say, the chambers are also arranged in a spiral form, but in a double series. A fifth family includes those shells in which the chambers are arranged round a common perpendicular axis in such a manner that each chamber occupies the entire length of the shell. The orifices of the chambers are placed

alternately at each end of the shell, and furnished with a curious tooth or process. The *Miliola*, already mentioned as constituting the Parisian building stone, will serve as an example of this family.

It is probable, although by no means certain, that the animals whose fossil shells, termed *Nummulites*, are found in great quantities in the chalk and lower tertiary strata, are also to be regarded as members of this class. No living example of this form of animal has yet been met with; but in a fossil state whole mountains in the neighbourhood of the Mediterranean consist almost entirely of their shells; and the Pyramids of Egypt, which have been reckoned amongst the wonders of the world from very remote ages, are chiefly built with a limestone that is almost entirely composed of *Nummulites*. In the time of Strabo it appears that the number of these fossils in the stones of the Pyramids had already attracted attention; and he tells us that the then commonly received opinion with regard to them was, that they were, the petrified remains of the lentils which had been used as food by the workmen employed in the construction of these vast edifices. Herodotus also notices the occurrence of these fossils in the Pyramids, and gives the above explanation of their origin.

CLASS II.—PORIFERA, OR SPONGES.

Although these animals are generally regarded, and perhaps justly, as standing on a sort of debateable ground between the animal and vegetable kingdoms, or at all events as occupying a frontier station in the former and approaching more closely to plants than any other animated beings, we have thought it better to defer the description of their singular structure and history until the completion of that of the *Rhizopoda*; not that the Sponges are necessarily to be regarded as more highly organized than the animals belonging to that class; but because many points, in their structure and development, are rendered far more clear by a previous knowledge of such creatures as the *Amœba* and its allies.

Sponge, in the state in which we usually see it, consists of a congeries of horny filaments, interlaced in every direction so as to form a most intricate network of intercommunicating cells. According to some observers, these filaments are hollow, constituting, in fact, so many horny tubes; but the researches of Dujardin and of Mr. Bowerbank tend to prove that this view was erroneous, and that the threads of which sponge is composed are solid throughout.

Imbedded in these threads, in the majority of sponges, are a number of very minute needle-shaped siliceous or calcareous particles of various forms; these are called *spicula* (Fig. 14). In most cases, the spicula are simply of an acicular form, slender and cylindrical, and pointed at both ends. In other instances they have a small knob at one end, whilst the opposite extremity is pointed, giving them exactly the appearance



Fig. 14.—Forms of Spiculae.

of minute pins; in others again, we find one end transformed into a fork with

two or even three prongs; or the whole spiculum consists of three or four spines of equal length.

In spite of their excessive minuteness, these spicula appear to be really small tubes, closed at both ends; for, according to Dr. Grant, to whose researches we are indebted for much valuable information upon the structure and physiology of these simple creatures, "when the spicula are examined through the microscope, after exposure to heat, we distinctly perceive a shut cavity within them, extending from the one point to the other; and on the inflated part of each spiculum we observe a ragged opening, as if a portion had been driven out by the expansion of some contained fluid. In those spicula which had suffered little change of form by their incandescence, I have never failed to observe the same cavity within, extending from one end to the other, and a distinct open rent on their side, by which the contained matter has escaped before the usual globular distension had taken place."

This framework, with its contained spicula, is, however, only a sort of horny skeleton, on which the true living portion of the sponge is supported. This consists of a coating of gelatinous matter, which is spread over all the fibres of the reticulated skeleton; its consistence is very like that of the white of an egg, and it runs freely away from the sponge when the latter is taken out of the water.

But when examined under the microscope, this gelatinous coating is found to consist entirely of an immense number of aggregated sarcode-cells, exactly resembling the animal described under the name of *Amœba*, as the simplest type of the *Rhizopoda*. Like that curious creature, each of these cells appears to possess a perfectly independent existence; each presents one or more contractile spaces; and even when detached from the mass of its fellows, enjoys the faculty of motion by the extension of its substance in various directions. Such, at least, is the case in the fresh-water sponges, or *Spongille*, the history of which has been most admirably detailed by Mr. H. J. Carter, of Bombay, from whose memoirs the following particulars, as to the structure and development of these creatures, are principally derived:—

"The sarcode cells above-mentioned are imbedded in an intercellular substance, to which the horny framework supporting the sponge appears to owe its origin. The cells, whilst still imbedded in this mucilaginous substance, are constantly changing their form; and as when separated from the common mass they are seen to take nutritive substances into their bodies in the same manner as the *Amœba*, it is very probable that the same phenomena occur when the creatures are still *in situ*.

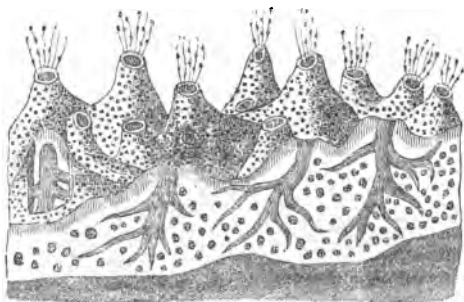


Fig. 16.—Section of a Living Sponge.

A glance at a piece of common sponge will show that its surface is everywhere perforated with an infinite number of minute holes, amongst which a considerable number of large openings are scattered. When a sponge is examined in a living state, a rapid stream of water may be observed issuing constantly from these larger orifices. This excurrent stream of water is rendered observable by the fact that it bears with it

a number of minute particles from the interior of the sponge (Fig. 16). This water is imbibed through the minute pores distributed in such profusion over the entire surface of the sponge; after passing through these, and traversing the cavities formed in every direction by the reticulated structure of the mass, it is collected into canals, by which it is finally conducted to the larger openings of the surface.

The primary objects of this continual flow of water through the substance of the sponge appear to be two-fold; first, the conveyance to the individual cells of which the living portion of the sponge consists, which may be regarded as so many stationary animalcules, the minute particles of nutritive matter necessary for their support and that of the general mass; and, secondly, the removal of faecal matter from the interior of the sponge. But nutrition and the removal of effete materials are not the only purposes to which it is applied—respiration, which, judging from analogy, is as necessary to the sponges as to other animals, must be effected by the medium of this current; and it also fulfils a very important part in the propagation of the species.

But although the imbibition and expulsion of water by the sponges has long been known, its cause long evaded the most persevering scrutiny of zoologists. By the older writers it was believed that the sponge possessed the power of sucking in the water through the larger orifices, and expelling it, after the lapse of a certain time, through the same openings by which it had penetrated its substance. Thus Linnaeus says—"Spongia foraminibus respirat aquam." Dr. Grant, however, a good many years since showed that the currents were continuous, and in one direction, although he failed to ascertain the means by which the motion of the fluid was produced. The opinion generally entertained, and indeed the only one by which this phenomenon could be at all accounted for, attributed the production of the current to the action of cilia; and this view has recently been confirmed by some interesting observations of Mr. Bowerbank's, upon a very curious species of sponge, the *Grantia compressa* (Fig. 17), not uncommon upon some parts of our coasts.

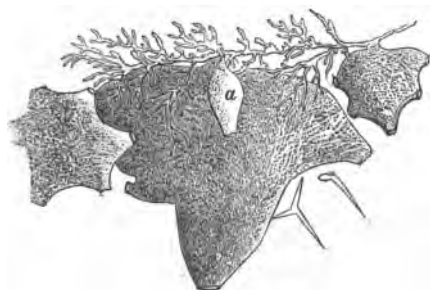


Fig. 17.—*Grantia compressa*.

This little sponge consists of a sort of white bag, formed of a thin spongy tissue, suspended by a narrow base, but exhibiting great variety in form. In its simplest state it is a small fusiform sac (a), with a single large opening at the apex; but when larger it acquires a more or less triangular pentagonal or hexagonal form, with a large opening at each of the angles. The general surface, as in all sponges, is perforated with innumerable minute pores, through which the water passes into the internal cavity, whence it is expelled through the larger openings. On cutting

open this sponge, and examining it with a magnifying power of about 500 diameters, Mr. Bowerbank found its inner surface to consist of a number of angular cells, formed by triradiate spicula, and terminated by a sort of perforated diaphragm, through which

the cilia could be seen in action. To obtain a transverse section of the substance of the sponge, he was compelled to tear it across as carefully as possible, and to examine the torn edges, when he found that a chamber extended from the diaphragm just mentioned to immediately within the incurrent orifices; this was lined with tessellated cells, many of which apparently bore very long ciliary organs, constantly waving to and fro, in spite of the rather rough treatment to which they had been subjected. The cells, when detached from the parent mass, still, in many cases, retain the organs by which this motion in the water is produced. In this state they bear a considerable resemblance to some infusorial animalcules furnished with a long filiform appendage.

The propagation of the sponge is effected in various ways. In some cases, little ciliated *gemmules* are produced in the gelatinous mass coating the fibres of the sponge; and after a certain period, becoming detached from the parent, are borne out through the large orifices by the action of the current already described. After this exclusion they swim about for some time, presenting a pretty close resemblance to some of the infusorial animalcules. But this life of freedom is not of very long duration; the little gemmule selects its place of attachment, fixes itself, and gradually becomes developed into a perfect sponge.

In the *Spongilla*, a somewhat different mode of reproduction occurs. Seed-like bodies are produced in the substance of the sponge, and always in the central or first-formed portion. These, in their earliest stages, consist of several cells, merely united together into a globular or ovoid mass, lying freely in cavities of the substance of the sponge. By degrees this mass of cells acquires a more definite form, and becomes enveloped in a capsule, on the surface of which, after a time, a finer crust of silicious spicula is developed (Fig. 18).

The spicula vary in form in the different species of *Spongilla*; in that from which the annexed figures are derived, they are arranged perpendicularly to the surface of the capsule, and dilated at each end into a stellate disc (*e*); in others they have no such regular arrangement; they are more or less curved and pointed, and either smooth or spinous.

The cells (*b*) inclosed within this silicious crust also undergo a considerable change in their progress towards maturity; they become nearly equal in size, and the granules contained in them (*a*), which originally resembled the granules of the ordinary sponge-cell, acquire four or five times this size. The capsule and silicious crust always have a small opening (*i*), through which the contents of the seed-like body may escape.

When the cells are pressed out of the cavity of the capsule under water, they soon swell up and burst; the germs contained in them becoming gradually diffused over the bottom of the vessel in which they are kept. These germs are of very minute size;

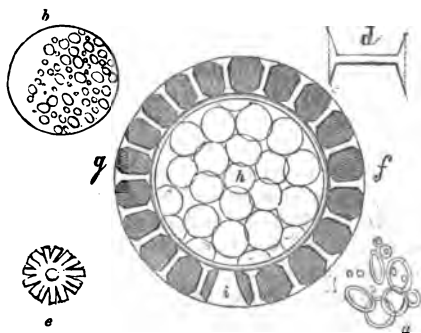


Fig. 18.—Development of *Spongilla*.

a, germs from cell; *b*, cell containing germs; *d*, spiculum; *e*, one of its terminal discs; *f*, spicular crust; *g*, capsule; *h*, cells; *i*, infundibular opening.

the largest of them not measuring more than 1-3000th of an inch in diameter. In form they present some resemblance to the corpuscles of the blood. In a few days the germs are found to have collected into separate groups, each inclosed in a mucilaginous substance. From these germs active animalcules are produced, exactly resembling the cells of which the gelatinous substance of the mature sponge is composed, and possessing the same power of locomotion by the extension of different parts of the body, even in a greater degree. These creatures, in fact, exhibit considerable activity; and during progression their bodies often assume the most fantastic forms. Their appetite also appears to be of the most voracious description. Of this Mr. Carter relates several curious instances; in one case he "saw one of these proteans approach a gelatinous body, something like a sluggish or dead one of its own kind, and equal to itself in size; and having lengthened itself out so as to encircle it, send processes over and under it from both sides, which, uniting with each other, at last ended in a complete approximation of the two opposite folds of the cell-wall, throughout their whole extent, and in the inclosure of the object within the duplicature. Even while the protean was thus spreading out its substance into a mere film, to surround so large an object, a tubular prolongation was sent out by it in another direction, to seize and inclose in the same way a large germ which was lying near it. After having secured both objects, the protean pursued its course rather more slowly than before, but still shooting out its dentiform processes with much activity. It took about three quarters of an hour to perform these two acts."

Not unfrequently combats take place between two of these singular creatures, when, if the size of the combatants be nearly equal, they merely twist about for a short time and then separate; but if there be any great disparity in bulk, the larger one swallows up his antagonist without remorse. On one occasion Mr. Carter saw a large protean seize a small one with its finger-like processes, and pass it under its body, so that the little one lay between the body of its captor and the glass in which they were both inclosed. "For a moment," says Mr. Carter, "the small protean remained in this position, when the cell-wall raised itself over it in the form of a dome, in which so-formed cavity the little protean began to crawl round and round to seek for an exit; gradually, however, the cell-wall closed in beneath it in the manner of a sphincter, and it was carried up, as it were, into the interior of the cell, securely inclosed in a globular transparent cavity resembling a hyaline vesicle, but much larger."

The gelatinous matter with which these groups of germs are invested appears to be identical with the intercellular substance of the mature sponge. After a time, threads of it begin to extend in straight lines on the surface of the glass, and connect the different masses of germ-cells.

The curious phenomena just described—indicating a much higher degree of vital power than we should at first sight be disposed to attribute to such an apparently inert mass as a sponge—are produced in a somewhat artificial manner; although there is every reason to believe that the same thing takes place naturally, and that at certain seasons the waters inhabited by the *Spongillæ* must swarm with germs escaped from their cells, and only seeking a suitable support on which to be developed into sponges. But it appears that the seed-like bodies possess yet another mode of development; for if one of them, when mature, be placed in water, it attaches itself to the surface of the vessel which contains it by means of a substance that issues through the opening in the capsule already mentioned. In this substance, when examined by the microscope, cells similar to those existing in the perfect sponge may be recognised, and the mass gradually

becomes developed into a compound creature resembling the parent from which it sprung.

As might be expected from the structure of these animals, they manifest but little indication of any general sensibility. It has indeed been stated that a shock, by which the entire mass is simultaneously affected, will produce a very distinct effect upon it. Thus it is said that if a piece of the *Spongilla* be allowed to fall into water from the height of a few inches, or otherwise exposed to the influence of a sudden shock, the prominent portions in which the vents are situated immediately contract very considerably, until the orifices are nearly closed. Other observers have declared that although no movement of contraction may be visible in a sponge, yet when the hand is laid upon it under water a peculiar tingling sensation is felt—due, they suppose, to some movement in the individual particles constituting its mass. This is rendered more probable by the consideration of the structure of the gelatinous coating of the sponge as already described.

Sponges grow attached to almost everything which may serve them as a point of support, whether fixed or floating; some cover rocks, shells, and other submarine objects, with a close spongy incrustation; whilst others shoot up a branched stem into the water; and others again hang freely from the seaweeds floating in the ocean. Sometimes they select very unexpected objects on which to take up their abode. Thus, in one case recorded by Dr. Johnston in his "Natural History of British Sponges," a specimen of the *Halichondria oculata*, a sponge not uncommon on some parts of the British coasts, was found growing from the back of a small live crab—"a burden," says the learned Doctor, "apparently as disproportionate as was that of Atlas,—and yet the creature has been seemingly little inconvenienced with its arboreal excrescence; for it is big with spawn in a state nearly ready for laying! Indeed the protection and safety which the crab would derive from the sponge might more than compensate the hindrance thus opposed to its freedom and activity. When at rest its prey might seek without suspicion the shelter afforded amid the thick branches of the sponge, and become easy captives; while, when in motion, scarce an enemy could recognize it under such a guise, and the boldest might be startled at the sight of such a monster."

Not the least wonderful circumstance connected with the history of the sponges is the power possessed by certain species of boring into substances, the hardness of which might be considered as a sufficient protection against such apparently contemptible foes. Shells, both living and dead, coral, and even solid rocks, are attacked by these humble destroyers, gradually broken up, and, no doubt, finally reduced to such a state as to render substances which would otherwise remain dead and useless in the economy of nature available for the supply of the necessities of other living creatures.

These boring sponges constitute the genus *Cliona*, and some allied genera. They are branched in their form, or consist of lobes united by delicate stems; they all bury themselves in shells or other calcareous objects, preserving their communication with the water by means of perforations in the outer wall of the shell. The mechanism by which a creature of so low a type of organization contrives to produce such remarkable effects is still doubtful, from the great difficulties which lie in the way of coming to any satisfactory conclusions upon the habits of an animal that works so completely in the dark as the *Cliona*—it will probably long remain so. Mr. Hancock, to whom we are indebted for a valuable memoir upon the boring sponges, published in the "Annals and Magazine of Natural History," attributes their excavating power to the presence of

a multitude of minute silicious crystalline particles adhering to the surface of the sponge; these he supposes to be set in motion by some means analogous to ciliary action. In whatever way this action may be produced, however, there can be no doubt that these sponges are constantly and silently affecting the disintegration of submarine calcareous bodies—the shelly coverings, it may be, of animals far higher in organization than they; nay, in many instances, they prove themselves formidable enemies even to living Mollusca, by boring completely through the shell. In this case the animal whose domicile is so unceremoniously invaded, has no alternative but to raise a wall of new shelly matter between himself and his unwelcome guest; and in this manner generally succeeds at last in barring him out.

The sponges vary exceedingly in form; and even the same species often assumes shapes the most different without any apparent cause. The forms under which the common sponge occur must be familiar to all our readers; and we have already given an example, in the *Grantia compressa* (Fig. 17), of a very different and singular form. Other sponges are arborescent, or at all events more or less branched, like the *Halichondria oculata* (Fig. 18); whilst others are of a cup shape.

Sponges occur in all seas, from the equator to the poles; but it is in tropical climates that they attain their greatest development, and exist in the greatest abundance.

CLASS III.—INFUSORIA.

General Characters.—In passing from the consideration of the preceding classes to that of the present group, we are not called upon to witness any very great advance in organization. Nevertheless, the differences between the two classes are all of a nature to show that the *Infusoria* certainly constitute a step in our progress towards the higher forms of animals.

The microscopic creatures constituting this class consist, it is true, of the same granular gelatinous matter, or sarcode, which we have seen to constitute the entire substance of the *Rhizopoda*; but this no longer presents itself in the form of a mere mass of jelly: each animal appears to be inclosed in a membrane, or layer of matter of a firmer texture than the rest of its substance; and motion, which cannot be effected as in the preceding class by the mere extension of portions of this substance in any desired direction, is now produced by the action of special organs. These organs are of very various construction. In some families we meet with long, thread-like appendages, which the animal twitches about in the water. These organs are sometimes single; in other instances the animal possesses two or more of them. From Ehrenberg they received the denomination of proboscis, although it does not appear that they are in any way connected with the process of nutrition; and this, with other opinions equally erroneous, published by the great microscopist of Berlin in his works upon these animals, have been adopted, without inquiry, by the generality of subsequent writers on natural history.

The most usual mode in which motion is effected in the *Infusoria*, is by means of *cilia*. The cilia are fine lappets or hairs, which exist either scattered or arranged in regular series over the whole surface of the body, or are collected in considerable numbers round the orifice of the mouth. They are moveable at the will of the creature, and serve, according to circumstances, either as organs of locomotion, or for the production of whirlpools or eddies in the water, by means of which the minute particles on which the animal feeds are brought within its reach. In some of the most highly organised

creatures of this class these ciliary hairs become converted into moveable bristles and hooks, by means of which the animal is enabled to crawl upon fixed objects in the water, and even to execute distinct leaps.

One striking difference between the animals of the present and those of the preceding classes is, that whilst in the latter by far the greater part of the animals are social in their habits, and in many cases seem almost to possess a sort of common existence, the *Infusoria* are aggregated together in only a few instances, and generally consist merely of a simple cell with its nucleus. Like the *Rhizopoda*, many of these animals are provided with a shell or shield; this, however, is never of a calcareous nature, but generally coriaceous or horny. In one family the animals are inclosed in silicious or flinty cases, of which great numbers are to be met with in a fossil state in the flints which occur in such quantities in the chalk hills.

Ehrenberg, and after him many zoologists who accepted both his facts and opinions without sufficiently examining into their correctness, attributed to these minute organisms, which certainly stand in need of no fictitious interest to render their history attractive and wonderful, a structure much more complicated than that of many animals which stand far higher in the scale of organization. By these naturalists we are given to understand that a number of small clear spaces, which are to be observed in the substance of these creatures, are in reality so many stomachs. Some slight difficulty attached to this view, however, as the most persevering researches failed in detecting any evidence of an intestinal canal uniting these cavities; and like many other conclusions at which Ehrenberg arrived rather too hastily, this opinion of his, with regard to the functions of the vacuoles, or clear spaces observed in the bodies of the *Infusoria*, has been disproved on more careful investigation. Thus these vacuoles are seen in many of these creatures to pass round and round the body, along with the rest of its contents, in a manner that renders the existence of the intestinal canal, by means of which they were supposed by Ehrenberg and his followers to be connected into one digestive system, an utter impossibility. They are found, in fact, to consist simply of small globules of fluid; they exist in those *Infusoria* which are destitute of a mouth, as well as in those which possess that organ; and they may be seen to disappear gradually as the fluid which constitutes them is absorbed into the gelatinous mass of the body. Ehrenberg, however, was so convinced of the existence of this alimentary canal, and of the stomachal functions of the vacuoles, that he gave the name of *Polygastrea*, or *many-stomached animals*, to this class; and even divided them into orders, from the supposed structure of an intestine which no one has ever yet succeeded in discovering.

The mode in which nutrition is effected in those *Infusoria* which possess a mouth will clearly show in what manner this mistake has arisen. These creatures feed upon small microscopic animals and plants, and probably upon such minute particles of decaying animal and vegetable matter as may be suspended in the water which they constantly inhabit.

The mouth is situated either at the anterior extremity of the body, where it generally forms a round opening, or at a greater or less distance from that extremity on the ventral surface; when in this position it is generally in the form of an oval or twisted slit. It is usually bounded by ciliated lips, capable of protrusion and retraction at the will of the animal; so that the mouth is frequently visible only during the act of eating. The cavity of the mouth is continued into a short oesophagus, and both are always clothed with delicate cilia. The minute particles of which the food consists are col-

lected together by the action of the stream produced by the cilia of the œsophagus, until they form a small ball, which then passes through the end of the œsophagus into the yielding substance of the body. But when imbedded in the parenchyma these balls occupy no particular place, but, like the drops of fluid aliment, follow the general circulatory movement of the gelatinous mass. It will be readily understood how the imperfect observation of these facts led to the supposition that the minute balls of indigo or carmine, to be discerned within the bodies of *Infusoria* which had been fed upon these substances, were contained in permanent natural cavities, hollowed out for the reception of nutritive matter, and that the clear spaces were similar cavities or stomachs, which for some reason had not been charged with food; but as we find that these apparently vacant spaces not only disappear by the absorption of their fluid contents into the general substance of the animal, but also that not unfrequently two or more of them will run together so as to form a single vacuole, we have pretty certain proof that they are not bounded by membranous walls, and that although there can be no doubt of the occurrence of the phenomena observed by Ehrenberg, the inferences which he drew from them, as to the complexity of the structure of these creatures, are quite untenable.

In these animals, as in the *Rhizopoda*, we find, in addition to the dark nucleus, one or several clear spaces which expand and contract alternately. These *pulsating spaces* are usually round, and sometimes exist in such numbers as to constitute a sort of long vessel. In other cases these spaces appear in the form of a star, of which sometimes the rays and sometimes the central space disappear during contraction. Although the pulsating spaces always occupy a determinate position, they appear to be quite destitute of membranous walls, as they may be seen during violent contraction to divide into two or more parts, which afterwards, during their expansion, again become confluent. It seems probable that we have, in these pulsating spaces, the first rudiments of the circulating system which we shall see attain such a high development in many of the higher animals,—that fluids are collected in these vacuoles, and then driven again through the spongy substance of which the body consists. Some naturalists have indeed supposed that they may have a communication, by means of some very delicate vessels, with the water in which the animal swims, so that at each contraction fluids might be expelled from the body, whilst at each dilatation water would be drawn in. This idea is, however, as yet wholly unsupported by observation, from which all that we can learn is, that contractile organs do exist in these creatures; and this, when we consider their minute size, is in itself a circumstance which may well serve to excite our wonder.

But when we come to inquire into the means by which these minute creatures are propagated, and into the processes by which, in a very short space of time, water, in which no trace of animal life was to be discovered, becomes densely populated by them, we shall find our surprise and admiration greatly increased. It will be as well, however, to defer the consideration of this subject till we come to treat of one of the most interesting forms of these animals, the *Vorticella*, as this creature presents some of the most curious phenomena to be witnessed in the animal kingdom.

In many *Infusoria*, and indeed principally in the very lowest and most doubtful members of the class, a bright red spot is observable near the anterior extremity. This has been described by Ehrenberg as an eye! But apart from the absurdity of attributing a distinct visual organ to creatures which have never for a moment been supposed to possess even a trace of a nervous system, the structure of these red spots has no resemblance whatever to that of an eye; and as many of Ehrenberg's eyed animalcules

have since his time been found to be only the spores of aquatic plants, and it is very probable that others will share the same fate as soon as their development shall have been further investigated, this notion of the existence of eyes, in the *Infusoria*, must be added to the many other instances of unsupported assumption which have unfortunately rendered the persevering labours of that zoologist far less beneficial to science than they might otherwise have been.

Most of these animals inhabit water; a few exist as parasites in the bodies of other animals. The aquatic species prefer clear to foul water, and are always to be met with in greatest profusion in places where *Confervæ* and other forms of aquatic vegetation are abundant. They are produced in great abundance in certain vegetable infusions when exposed to the air; and this circumstance, discovered by Leeuwenhoek in 1676, has always been regarded as one of the principal evidences in favour of the doctrine of *spontaneous generation*—a doctrine which was at one time in considerable repute, and which is not without its supporters even in the present day. According to this theory an organic fundamental matter is everywhere distributed. Of this, it was supposed, the organs of the higher animals and plants consisted; and to this, if the theory were correct, they would return on the death and consequent decay of the organism. It was further supposed that this fundamental organic matter possessed the faculty of organizing itself, under the simultaneous influence of air and moisture, so as to produce certain determinate forms of plants and animals, especially moulds and *Infusoria*; the animal or vegetable nature of the resulting creature, as well as its specific form, being dependent, said the theory, upon external circumstances. What these external circumstances were, however, and in what manner their influence produced the infinite variety of form observable in these lowly organisms, the theory was unable to say. It was settled, however, that for the purpose of spontaneous generation three things were necessary—namely, the organic substance, water, and air.

Later investigations, nevertheless, soon showed that there was some flaw in this theory, specious as it might appear; and although even our present knowledge is not sufficient to enable us to account with certainty, in all cases, for the appearance of animals in infusions, and in the interior of other creatures, a very simple experiment will serve to demonstrate the falsity of the theory of spontaneous generation. If an infusion be boiled and placed in an air-tight vessel, living organisms are never produced in it; but as soon as it is opened, and exposed to the air, the same creatures are produced in it as if it had never been boiled. It would appear from this that the access of air was the condition necessary for the spontaneous production of living organisms. But if the infusion be boiled in a flask to which no air can have access, except by passing through a vessel filled with sulphuric acid, or some other substance which, possessing no power of acting upon the air itself, is yet capable of destroying any organised bodies which might otherwise be borne in with the air, the apparatus may be allowed so stand for weeks or months, and the air contained in it constantly changed during the whole period without the production of a single animal. But when the similar contents of another flask are treated in exactly the same manner, except that the renewing of the air is effected merely through an empty tube, without the intervention of any corrosive substance, the infusion is soon filled with microscopic creatures of all kinds. This experiment proves clearly that the production of these minute organisms, in new situations, is due to their presence, or to that of their germs in the atmosphere, and that no new beings result from the mutual contact of organic matter, water, and pure air.

Minute as these creature are, and some of them are said not to exceed the 1-20000th

of an inch, whilst the giants of their race are not more than 1-50th of an inch in length, they are not without their importance in the economy of the world. By their prodigious numbers they amply compensate for their want of size. Every drop of water on the face of the globe appears to contain them in greater or less profusion; and this, coupled with their great fecundity (for it has been calculated that the progeny of some animalcules would amount to upwards of two hundred and sixty-eight millions in four weeks), may readily convince us of the vast quantity of food furnished by these creatures to others a little higher in the scale, which in their turn become the prey of larger animals.

One of the many extraordinary facts, connected with the natural history of the *Infusoria*, is the power which many of these animals possess of retaining their vitality for a long time, when the water which they had been inhabiting has become dried up with the heat of summer. They will remain thus inclosed in the dry and hardened mud, which frequently, as we all know, becomes baked by the action of the sun into a condition in which the last thing we should suspect would be the presence of animal life, especially of such delicate organisms as these, until the return of wet weather recalls them from their dormant state to activity and enjoyment; or they may be taken up from the surface of the drying pool by the action of wind, and blown about in the atmosphere until they meet with some moisture, in which they may be developed, and may propagate their species. It is probable, in fact, that much of the dust which we so frequently see floating, apparently in the beams of the summer sun, consists of either the bodies or the germs of *Infusoria*.

Divisions.—The classification of the *Infusoria* presents considerable difficulty, partly arising from their excessive minuteness, which renders the assistance of our best microscopes necessary to enable us even to see many of them, and partly from the impossibility of avoiding confusion from the intermixture of the germs of more highly organised animals, and some plants in various stages of development.

The class of *Infusoria*, as circumscribed by Ehrenberg in his "*Infusionsthierehen*," published in 1838, included a curious mixture of heterogeneous elements. It was divided into two great groups, the *Polygastrica* and the *Rotifera*, with the latter of which we have nothing to do here; the animals composing it belonging to a far higher type of organisation. But even in the *Polygastrica*, a vast number of species, and especially the whole families of *Closterina*, *Bacillaria*, and *Volvocina*, are found to be true plants; and after the rejection of these we find a considerable quantity of creatures, in which the possession of a moveable filiform appendage, and the existence of a red spot, are the only characters, on account of which they can be referred to the animal kingdom. Many of these have been already found to be truly the active germs of *Conferve*; and it is probable that more extended investigations will, before long, show that many, about which we are still doubtful, are also to be referred to the vegetable kingdom. These species belong to Ehrenberg's families *Monadina* and *Cryptomonadina*. Lastly, his family *Fibriolina*, including the well known eels of paste and vinegar, must be rejected altogether, as it includes a heterogeneous assemblage of microscopic plants and embryonic forms of worms. After the separation of these, the animals still referable to the class of *Infusoria* are sufficiently numerous and interesting. They may be divided into two orders, characterized by the presence or absence of a mouth in the animals composing them.

The first order, the *Astomata*, or *mouthless Infusoria*, includes all those in which the mouth is wanting. They appear to be nourished entirely by the absorption of fluid

matter through their outer surface, and have never been seen to take solid food. The first family of this order, the *Astasidae*, is distinguished by an extremely contractile body, generally of a green or red colour; most of them possess one or two red points. The animals belonging to one of the genera of this family (*Englena*, Fig. 19), which are



Fig. 19.—*Englena viridis*, 350 diameter in various states of contraction.

generally of a green or red colour, frequently cause the water they inhabit to appear of one of these colours, in consequence of their sudden appearance in myriads. It is not improbable, however, that some of the creatures included in this group may prove to be vegetable organisms.

The family *Dinobryidae* very closely resembles the preceding; but the animalcules of which it is composed are furnished with

a horny case, within which they can retract themselves at pleasure.

In another family, the *Peridiniidae*, the animals are also furnished with a horny or silicious shell or carapace; but in these the shell has a transverse or oblique slit (Fig. 20) furnished with a circle of cilia; it is also frequently produced into very remarkable horn-like processes. Motion in these animals is effected not only by means of these cilia, but also by the aid of a filiform appendage, which can be protruded from a particular spot in the carapace. The silicious coats of these creatures are found in great profusion in the flints of our chalk hills.

The fourth family of the astomatous *Infusoria*, the *Opalinidae*, consists entirely of animals which have hitherto

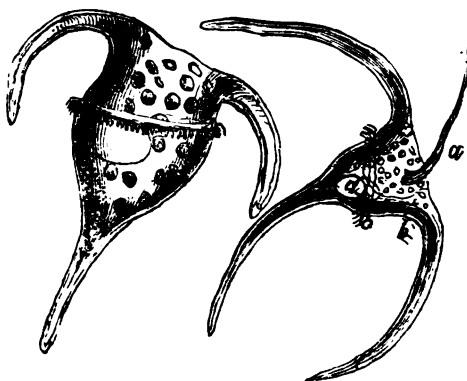


Fig. 20.—*Peridinium*, 300 diameter.
a, Filiform appendage. b, carapace. c, fringe of cilia.

only been found living as parasites in the intestines of frogs and of some worms. The bodies of these creatures are colourless, and of a perfectly glassy transparency, so that their structure may be studied with the greatest ease; and there can be no doubt as to the complete absence of anything like a buccal orifice. Their motions are effected entirely by means of cilia, which are arranged in oblique lines upon their flat oval bodies.

From these simple creatures we turn now to the consideration of the far more numerous and interesting forms of Infusorial animalcules, in which the presence of a mouth indicates a higher degree of organization and a more extended sphere of action. They form the order *Stomatoda*. The first family of this order, the *Monadidae*, consists of roundish or oval animalcules, whose minute size renders their examination difficult even with our very best glasses. Their motions are generally produced by means of filiform appendages, of which each animal possesses one or more. Some of them

measure only 1-20000th of an inch in length; and it has been calculated that a cupful of water may easily contain a number of these animalcules considerably larger than that of the entire human population of the earth. Such an assertion as this may well raise our astonishment to the highest pitch, when we consider that each of these living atoms possesses a mouth well furnished with cilia, through which it is able to introduce into its substance particles of solid matter of a size so small that, until collected by these little creatures, our highest magnifying powers will fail to reveal their existence.

We now come to a family which includes some of the most beautiful of the infusorial animalcules, and in which we meet with phenomena more curious than any we have yet witnessed, and perhaps as wonderful as any that will be presented to our notice, when studying the natural history of the higher classes of animals. This is the family of the *Vorticellide*, or *bell-animalcules*. The animals of which it is composed are characterized by the possession of a fringe of rather long cilia, surrounding the anterior extremity, which can be exerted and drawn in at the pleasure of the creature; by the vibration of these cilia the little animal, which usually has somewhat the appearance of a miniature wine-glass supported upon a very long stalk, can produce a sort of vortex in the water, by which smaller animals and minute floating particles of alimentary matter are drawn into the mouth. Some of these little creatures are furnished with a horny case for the protection of their delicate bodies, whilst others are quite naked.

The genus *Vorticella*, from which the name given to the family is derived, consists of animals of the latter description. Each of these little creatures is placed at the top of a long flexible stalk, the other extremity of which is attached to some object, such as the stem or leaves of an aquatic plant. This stem, slender as it is, is nevertheless a hollow tube, through the entire length of which runs a muscular thread of still more minute diameter. When in activity, and secure from danger, the little *Vorticella* stretches his stalk to the utmost, whilst its fringe of cilia is constantly drawing to its mouth any luckless animalcule that may come within the influence of the vortex it creates; but at the least alarm the cilia vanish, and the stalk, with the rapidity of lightning, draws itself up into a little spiral coil. But the *Vorticella* is not wholly condemned to pass a sort of vegetable existence, rooted, as it were, to a single spot by its slender stalk; its Creator has foreseen the probable arrival of a period in its existence when the power of locomotion would become necessary, and this necessity is provided for in a manner calculated to excite our highest admiration. At the lower extremity of the body of the animal, at the point of its junction with the stalk, a new fringe of cilia is developed; and when this is fully formed the *Vorticella* quits its stalk, and casts itself freely upon its world of waters. The development of this locomotive fringe of cilia, and the subsequent acquisition of the power of swimming by the *Vorticella*, is generally connected with the propagation of the species, which, in this and some of the allied genera, presents a series of most curious and complicated phenomena.

In these, as in all other *Infusoria*, the simplest mode in which propagation is effected, is by the division of the individual into two or more parts. This division, as we have already stated when speaking of the *Protozoa* in general, commences in the nucleus, which, in the *Vorticella*, is of a band-like form. Before and during this division of the nucleus the body of the creature acquires a considerable increase in breadth. A constriction afterwards makes its appearance in the middle, which,

continually increasing in depth, at last divides the body of the animal into two halves, each of which is now found to constitute a perfect *Vorticella*. Only one of these, however, is to remain in quiet possession of the original stalk; the other, consequently, develops a fringe of cilia at its lower extremity, detaches itself, and swims away to seek a new home. Having fixed upon a convenient spot for its purpose, it attaches itself, by the hinder part of its body, to the place it has selected; the cilia then disappear, and a new stalk is gradually developed, until the new animal exactly resembles that from which it sprang.

The *Vorticella* also possess another means of propagation which is denied to all the other *Infusoria*, with the exception of a few nearly allied genera, although we shall meet with it again in other classes of animals. This mode of reproduction is called *germination*. It consists in the production of a sort of bud, which gradually acquires the form and structure of the perfect animal. In the *Vorticella*, these buds, when mature, quit the parent stem after developing a circle of cilia at the lower extremity, and fix themselves in a new habitation in exactly the same manner as the individuals produced by the division of the bell.

It might be thought that animals endowed by nature with the power of increasing their numbers by the continual division of their very substance, would stand in no need of any further provision for the continuance of their species; that these means of reproduction would amply suffice to enable them to fulfil the scriptural injunction to "increase and multiply, and replenish the earth." We find, however, that other and more complicated contrivances are employed for the same end; so that we need not wonder at the great rapidity with which these creatures multiply in situations favourable to their development.

At an earlier or later period of their existence, the *Vorticella* withdraw the disc surrounded by cilia which forms the anterior portion of their bodies; and contracting themselves into a ball, secrete a gelatinous covering which gradually solidifies, and forms a sort of capsule, within which the animal is completely inclosed. Occasionally, this process, by which the *Vorticella* is said to become *encysted*, takes place, whilst the creature is still attached to its stalk; but more commonly the circle of cilia, already mentioned, is first developed at the posterior portion of its body, and the *Vorticella* becomes encysted whilst swimming freely through the water. Even when the animalcule undergoes this change, whilst still supported on the stalk, the latter soon disappears, leaving the encysted *Vorticella* free.

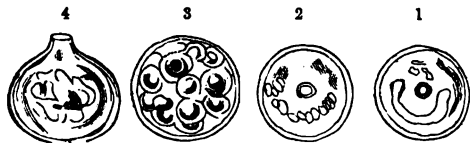


Fig. 21. Development of *Vorticella*.

The body of the animal (Fig. 21, 1) now appears almost homogeneous in its structure, but still contains the nucleus unchanged, and also incloses a small round cavity filled with fluid, which represents the contractile space of the original *Vorticella*, but no longer exhibits the pulsations characteristic of that organ in the active animal. At this point the history of the creature becomes still more complicated. Sometimes its further progress commences by the breaking up of the nucleus into a number of minute

oval discs (Fig. 21, 2), which swim about in the thin gelatinous mass into which the substance of the parent has become dissolved. The body of the parent animal inclosed within the cyst now becomes apparently divided into separate little sacs or bags (Fig. 21, 3), some of which gradually acquire a considerable increase in size, and at length break through the walls of the cyst. After a time one of these projections of the internal substance bursts at the apex; and through the opening thus formed the gelatinous contents of the cyst, with the included embryos, are suddenly shot out into the water (Fig. 21, 4), there to become diffused, and give rise to a new generation of *Vorticellæ*.

But this is only one of the phases of the development of these encysted *Vorticellæ*; another and a still more remarkable one remains behind. In other cases, instead of producing a number of little active embryos in its interior, the encysted *Vorticella* extends sometimes in one direction, sometimes in another (Fig. 22, 1), at the same time protruding from all parts of its surface a number of slender filaments, terminated by minute knobs, similar to the processes by means of which we have seen motion produced in the Rhyzopoda. Sometimes a portion of the creature is thrust out, so as to form a new stalk (Fig. 22, 2), by which it attaches itself to objects in the water.

These reproductive forms of the *Vorticellæ* have long been known to microscopic observers, and several of them were described by Ehrenberg as belonging to very various genera. From the name *Acineta*, given by that author to one of these genera, they are now denominated the Acineta-forms. Two of them are represented in Fig. 22; the first closely resembles the *Actinophrys sol* of Ehrenberg; and the second is described by him under the name of *Podophrys fxa*. Both these, however, are only forms of one species, the *Vorticella microstoma* of Ehrenberg.

But the final object of this singular metamorphosis still remains to be described. The nucleus, which at the change of the encysted animalcule into the Acineta-form was still distinctly observable, becomes entirely and altogether converted into an active young *Vorticella* (Fig. 22, 2 *b* and 3), acquiring an ovate form, with a circlet of cilia round its narrower extremity, and presenting, at the opposite end, a distinct mouth. Within this young animal, whilst still inclosed in the body of its parent, we see a distinct nucleus and the usual contractile space of the full grown creature. When mature, the offspring tears its way through the membranes inclosing the Acineta, which however immediately closes again. The latter continues protruding and retracting its filaments, and soon produces, in its interior, a new nucleus, which, in its turn, becomes metamorphosed into a young *Vorticella*.

The same faculty of inclosing themselves in a cyst appears to be made use of by the

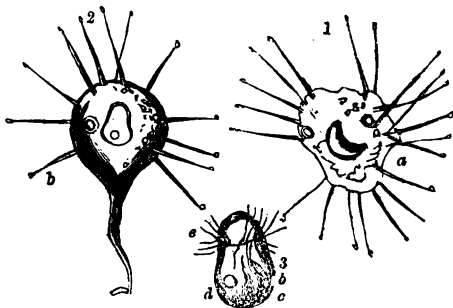


Fig. 22.—Acineta-forms of *Vorticella*.

a, nucleus; *b*, young *Vorticella*; *c*, retracted interior cilia; *d*, contractile space; *e*, posterior ciliary fringe.

Vorticella as a means of self-preservation when the water in which they have been residing dries up. When the animal is thus encased, the mud of the bottom of the pool may be baked quite hard in the sun without doing it the least injury; and in this state the creatures are often taken up by the wind with the dust which it raises from the surface of the parched ground, and borne along to great distances, so as to make their appearance in most unexpected localities (they are frequently found in roof gutters), where the first shower of rain calls them back to active life. These processes are repeated in several of the allied genera with so little variation, as far as observations have hitherto shown, that it will be unnecessary to mention them more particularly. We may, however, before quitting this interesting family, describe a few of the leading forms which it presents to our notice.

We have already seen that each *Vorticella* is supported upon a flexible stalk; and that when a bud is produced from any part of the animal, it is cast off by its parent to shift for itself as soon as the organs necessary for its separate existence are developed. This character serves to distinguish the true *Vorticellæ* from the other members of the family; in which, however, we meet with considerable diversity of form. Thus in the genus *Carchesium* the stalks are still flexible, and, as in the *Vorticellæ*, coil themselves up in an instant at the slightest alarm; but each main stalk, instead of being surmounted only by a single bell, bears several branches equally irritable with itself, and each terminating with a separate, and, to a certain extent, independent animal. In the *Epistylis nutans* the stem is also branched; but here, instead of a flexible contractile filament, we find a stiff bristle-like tube, at the extremity of which the creature is situated. During its contraction it turns back with a sudden jerk, and hangs down from the stalk as if broken.

In another curious genus (*Ophrydium*, Fig. 23), the animals, instead of being supported freely upon a stalk, are imbedded in the substance of a gelatinous mass, from the surface of which the anterior extremity of each animal projects more or less. The gelatinous masses, in which the animalcules are thus imbedded, may be met with of all sizes, from that of a pea to that of a small apple.

In some nearly allied species forming the genus *Vaginicola* (Fig. 24), the body of each animal is inclosed in a separate minute horny sheath, within which it can retract at pleasure.

In the *Stentor*, or *Trumpet animalcule* (Fig. 25), which is also generally referred to this family, the animal does not consist exactly of a bell supported upon a distinct

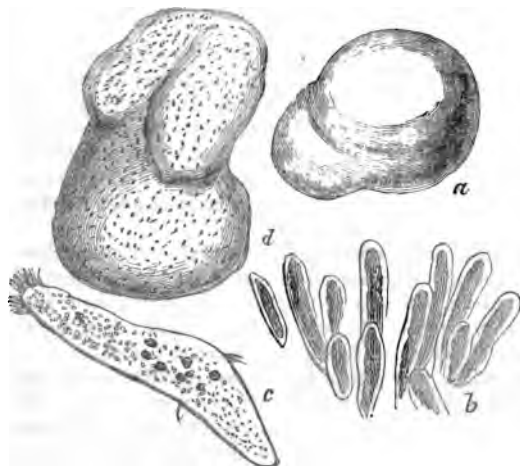


Fig. 23.—*Ophrydium Versatile*.

a, d, masses of animalcules; *b*, animalcules *in situ*; *c*, a single animalcule highly magnified.

stalk; its body is of a trumpet-shape, and adheres to its point of attachment by its



Fig. 24.—*Vaginicola Crystallina*.
350 diameter.



Fig. 25.—*Stentor Mulleri*.
75 diameter.

smaller extremity. The body in these animals is entirely covered with cilia, and the creature generally possesses the power of retracting the elongated tail-like portion by which it attaches itself to other objects, and swimming away in search of a new habitation. Lastly, the *Trichodinæ*, or *Urnanimalcules*, are never attached to a stalk, but generally swim about freely by means of the cilia with which the extremities of their bodies are fringed.

The remaining families of the *Infusoria* present us with few points of interest at all comparable to those exhibited in the history of the *Vorticelliæ*, although even in these many curious and interesting forms occur. They may be divided into two great families—the *Trichodinæ* and the *Setifera*. The former of these contains all the mouth-bearing Infusoria not belonging to either of the preceding families, in which motion is entirely produced by the agency of cilia; whilst the animals included in the second possess, besides these, bristles or hooks adapted for climbing or creeping upon aquatic plants.

¶ The animals forming the first of these families exhibit a great diversity of form and structure. In some the surface of the body is naked, and the cilia are confined to the anterior extremity of the body, where they form a circle surrounding the mouth. They constitute the sub-family *Enchelina*. In these, the opening through which the faecal matters are rejected is situated at the hinder extremity; whilst in the *Vorticella*, to which they present the greatest resemblance, the remains of the food are cast out, either through the mouth itself, or by an opening in the immediate neighbourhood of the mouth. The anterior portion of the body is sometimes produced into a long flexible neck, which the animal twists about in every direction, and which appears to serve, in some respects, as an aid in its motions.

A second sub-family, the *Trachelina*, is distinguished by having the whole or greater part of the body covered with fine cilia, generally arranged in longitudinal series, of which those surrounding the mouth are a little longer than the rest. The anal opening is variable in its situation. The *Paramecium* is an example of this group.

In a third group we meet with a very singular apparatus, consisting of a cylinder of fine horny fibres, which surrounds the mouth (Fig. 26 *a*). The food of the animal is seized by this apparatus, and drawn gradually into the oesophagus; an animalcule is represented in this position at *b* in the annexed figure. These form the sub-family *Nassulina*.

In the last great family, the *Setifera*, we meet with a very singular modification of the ciliary structure. In addition to the cilia, which, as usual, surround the mouth, the ventral surface, in these creatures, is furnished with a number of bristles or hooks, by means of which they are enabled to run or creep upon fixed objects in the water.

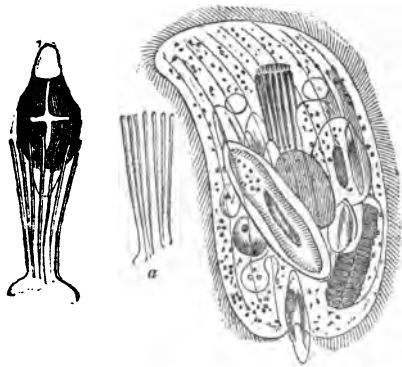


Fig. 26.—Chilodon Cucullus.

Before quitting the consideration of the *Protozoa*, we must refer to a curious group of minute parasitic creatures which appear to be more nearly allied to the *Infusoria* than to any other class in the animal kingdom. These microscopic parasites, called *Gregarina*, are found in a situation where, probably, few of our readers would dream of seeking for such creatures. They inhabit the intestines of the common garden worms, insects, and many other members of the articulate division of animals, and are but rarely to be met with in animals of any other group. These animals are generally of a cylindrical or somewhat elliptical form, although sometimes a sort of head appears to be produced by the constriction of the anterior extremity of the body (*c d*), and this head-like portion is occasionally furnished with a curious soft process and lobes. The body, in all cases, however, consists entirely of a sort of transparent homogeneous cell, containing an albuminous fluid, in which a nucleus and a number of minute granules may be observed. They are exceedingly sluggish in their movements, which are effected by the contraction of the body, although a few possess true cilia, and others are furnished with stiffer immoveable hairs.

Curious as the habitation selected by these creatures may appear, we shall find something still more singular in the method appointed by the Creator for the continuance of the race of these simple cells. It had long been known to naturalists that many *Gregarina* consisted only of a single cell, whilst others appeared to be composed of two separate complete cells, each containing a nucleus. Upon this character, and the differences in the forms of the cells thus united, many genera, and even families, have been established amongst the *Gregarina*,—the authors describing these various forms no doubt building high and flattering hopes of immortal reputation upon their microscopic labours. But more recent observers have ruthlessly dashed these hopes to the ground, by showing that these double cells, with all their diversity of form, only represent different stages in the history of the propagation of the simple animals. The mode of reproduction which prevails here is one which we shall meet with in no other group of animals; although something very analogous takes place in some low forms of plants.

It is effected in the following manner :—Two *Gregarinae* become united by some part of their bodies, and cling together so firmly that their separation appears to be impossible. By degrees they lose their original form, until at length they constitute an oval mass, slightly constricted in the middle, but still divided into two distinct cells by a transverse partition. Now a transparent capsule is formed round the compound body, whilst the two nuclei, which have hitherto retained their original appearance, gradually disappear, and the bodies of the animals become converted into a number of granules. The process of development continues within the capsule; the granules, or germs, become smaller and more numerous; the partition between the two cells finally disappears; and the mature sac either passes entire from the body of the animal in which it is contained, or bursting within its intestine, allows the numerous germs to be evacuated at once.

So far careful and patient investigations have traced the history of these minute parasites; but the ulterior development of the germs, and the mode in which the young *Gregarinae* again find admittance into the bodies of their destined victims, are still enveloped in mystery.

DIVISION II.—RADIATA.

General Characters.—The animals arranged under this second division of the animal kingdom, are generally distinguished by the radiate form of their bodies,—that is to say, all the parts of which the creature is composed are arranged circularly round a common centre. In some instances, however, this radiate arrangement of the organs is not readily recognizable, although in other respects the animals approach the true radiate forms so closely, that it is difficult to place them in any other position.

In complexity of structure some of the lower forms of *Radiata* scarcely seem to exceed the simple creatures belonging to the preceding division, consisting of a mere bag or digestive cavity furnished with a few tentacula or feelers. Still, even in these, an advance in organization is perceptible; for although the substance of which they are composed appears to differ but little from the sarcode of the *Protozoa*, they can never, like these, be regarded as mere aggregations of cells, each capable of a separate and independent existence. But as we advance from these low forms towards the higher classes, we find the complication of structure constantly on the increase: instead of a membranous bag, either side of which will serve equally well as a skin or a stomach, we soon find a marked distinction between the outer coat and the membrane lining the digestive cavity; and this goes on increasing until in the highest forms (some star-fishes and sea-urchins), the former consists of a most complicated mosaic of calcareous plates, and the latter becomes converted into a long convoluted intestine, furnished sometimes with a very curious masticating apparatus in the mouth, and with an anal opening for the discharge of the refuse of digestion. The other organs of the body also partake of the same advancement: a nervous and circulatory system, and a complicated system of locomotive organs, gradually make their appearance; singular organs, supposed to be organs of sense, occur in some forms; and the function of reproduction, which in the lower forms appears to be principally executed by a plant-like budding and division of the parental substance, is at last confined to certain organs exclusively appropriated to that purpose.

The nervous system, when present, is still very imperfect, and almost rudimentary;

it partakes of the radiate arrangement of the body; and in its most perfect condition consists of a ring of ganglia surrounding the mouth, and giving off nervous filaments to each of the segments of which the body is composed. The organs which have been regarded as special organs of sense, occur by no means universally; they will be noticed in treating of the groups in which they are met with. A system of vessels exists in many of these animals; but it is only in the highest class that we find a distinct circulatory system, with a sac-like heart for the propulsion of the nutritive fluid. In these also the function of respiration is sometimes assisted by a system of aquiferous vessels, which serve to conduct the water to different parts of the body; but this is the only trace of any special respiratory apparatus in the animals under consideration. In the majority, respiration appears to be effected by the simple contact of the surface of the animal with the circumambient fluid. The functions of reproduction and locomotion are performed in such very different modes in the different classes, that it will be as well to leave their consideration till we come to treat of these subordinate divisions.

A faculty which is possessed by most of the Radiata is that of emitting phosphorescence in the dark, especially when irritated or disturbed. Although they have this power in common with some other groups of animals, it is to the gelatinous free-swimming creatures of this class that the phenomenon, well known as the luminosity of the sea, is principally to be attributed. This phenomenon, the occurrence of which is by no means uncommon on our own coasts in calm weather, is exhibited in the greatest splendour in the seas of warm climates. The whole surface of the ocean is there suffused with a pale light, which acquires the greatest brilliancy when the water is in any way disturbed. The passing ship leaves a brilliant illumination in its wake; the waves, in their gentle heavings, break into sparks and flashes of light; the oars of moving boats are seen dripping with living jewels when taken out of the water, and each stroke produces a sparkling streak. This general luminosity is due to innumerable minute animals, amongst which larger and more brilliant species may be seen swimming in splendour, some like balls of living fire, others like waving bands of flame. The majority of these creatures belong to this division, and principally to the class of *Discophora*, well known to most of us as Medusæ or jelly-fishes. In some localities the *Noctiluca*, a singular little animal belonging to the class of *Siphonophora*, also plays an important part in the production of this phenomenon. The phosphorescence is supposed to be produced by the slimy fluid with which the bodies of these animals are generally endued, and in which the urticating properties possessed by many of them also appear to reside.

Divisions.—The Radiata may be divided into five classes; but their classification, in spite of the great attention which has lately been paid to them, still remains involved in considerable uncertainty. The first class, containing the *polyypes* (POLYPI), consists of animals of a more or less cylindrical form, which are generally attached by one extremity to some solid submarine substance, and furnished at the other with an oral opening surrounded by tentacles. Most of these are compound animals, constructing a common horny or calcareous domicile; each polype inhabiting a separate cell, within which it can contract itself at pleasure.

The second class, the *DISCOPHORA*, includes the animals well known as jelly-fish. They consist of a more or less convex disc or umbrella (Fig. 27), at the centre of the lower surface of which the mouth is situated, generally surrounded by four arms. The animals swim freely in the water by the alternate contraction and expansion of the

disc, the circumference of which is generally furnished with filiform tentacles of great extensibility. The body is naked, gelatinous, and transparent.



Fig. 27.—*Pelagia*.

The animals constituting the third class, the CTENOPHORA, are, like the preceding, of a gelatinous consistency and glassy transparency; but the body, instead of being discoid, is generally more or less ovate in its form (Fig. 28), and the animals swim by the action of a number of cilia arranged in rows upon their surface. The mouth is situated at the anterior extremity of the body; and at the opposite end there is an anal opening. Most of them possess a pair of extremely extensible filiform tentacles, which are generally concealed, when not in action, in small cavities formed in the substance of the body.

The fourth class, the SIPHONOPHORA, is composed of creatures, the structure of which is still in many cases but little known. Like the animals of the two preceding classes, they swim freely in the sea, and their bodies are also gelatinous and transparent; they are generally

furnished with a peculiar cartilaginous support, and with closed air-bladders, which serve as floats to maintain them at the surface of the ocean.

In the fifth and last class, the ECHINODERMATA, we find the most highly organized forms of *Radiata*. These possess a coriaceous skin, in which a deposit of calcareous matter takes place, often to such an extent as to form a shell inclosing all the soft parts of the animal. They generally creep along the bottom of the water, by means of a great number of tubular suckers, which can be protruded at pleasure through openings left in the plates of which the calcareous covering is composed. The radiate arrangement of the parts is perhaps more distinctly recognizable in some of these animals (the common star-fish, for example) than in any other members of this division; it is in these only that any trace of a nervous system has been discovered.

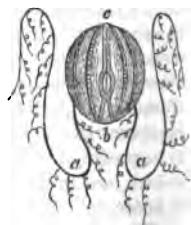


Fig. 28.—*Cydippe*.

a a, tentacula; *b*, mouth;
c, anal opening.

CLASS I.—POLYPI.

General Characters.—The class of Polypi includes a great number of animals, most of which are of very simple construction. They are all aquatic in their mode of life; and by far the greater number inhabit the sea, a very few only being found in fresh water. Most of them live in societies of greater or less extent, supported on a common stock, or *polypidom*, which is sometimes horny, sometimes calcareous. The little creatures are either imbedded in cavities, formed immediately in the substance of

this support, or in a sort of flesh which sometimes incrusts it, or inclosed (as in the horny polypidoms) in minute cups or tubes, from which the body can be protruded at pleasure, and again retracted at the approach of danger, or during repose. These social polypes are always of small size, although the structures produced by the united labours of successive multitudes are often sufficient to produce important changes in the face of nature. Many of the solitary species, however, attain a considerable magnitude.

The bodies of these animals are generally cylindrical in form, with a fringe of *tentacles*, or arms, frequently consisting of a considerable number, surrounding the anterior extremity, in the centre of which the mouth is situated. The mouth is the only aperture of the digestive cavity; it is quite destitute of any masticating apparatus.

The skin in the compound polypes, which are able to retract themselves into firm cells or tubes, is exceedingly soft and tender; but in the solitary species it frequently acquires a leathery consistence, forming a closed sac, within which the more delicate tentacles can be retracted at pleasure. In many cases the skin contains urticating organs, consisting of minute transparent vesicles, from which long spiral threads and a caustic fluid are emitted, which cause a stinging sensation on coming in contact with the skin.

Reproduction takes place in these animals both by means of ova, and by germination or budding. The sexes are always united in the same individual.

Divisions.—The *Polypes* are commonly divided into three orders. In the first, the *Hydroida*, the animals are generally compound, and invested with a horny tubular polypidom; the digestive cavity is excavated in the substance of the body without any proper lining membrane; and the reproductive organs are always external. In the second order, the *Asteroida*, the polypes are always compound; the mouth is surrounded by eight tentacles; the digestive cavity is lined with a membrane, and the ovules are produced in the interior of the animal. The polypes in this order are imbedded in a more or less fleshy mass, which is generally supported on a horny or calcareous axis. The polypes of the third order, the *Helianthoida*, are single, and either possessed of a certain power of locomotion, or imbedded in a calcareous polypidom. The mouth is generally surrounded by a great number of tubular tentacles; the stomach is furnished with a distinct lining, and the ovaries are internal.

ORDER I.—HYDROIDA.

General Characters.—It is in the polypes of this order that we find the nearest approach to the preceding division. The body in these generally consists of a homogeneous aggregation of visicular granules, held together by a sort of glairy intercellular substance, and capable of great extension and contraction; so that the creature can at pleasure assume a great variety of forms, extending its body and tentacles until the latter become so fine as to be almost invisible, and again retracting itself until it acquires the appearance of a small gelatinous mass. The tentacula which surround the anterior extremity are irregular in number; they are capable of extension to a very great length when seeking for prey; and on coming in contact with any object floating through the water, they immediately twine round it, and convey it to the mouth. In some genera the tentacles appear to be tubular, the internal cavity being continuous with that of the stomach. To assist in the capture of living prey, their surface is commonly roughened with a series of granules, which in some cases contain a curious poisonous or urticating apparatus. The mouth, which is situated in the

centre of the circle of tentacles leads directly into a simple digestive cavity, which is not lined with any membrane.

By far the greater number of these animals live in societies of greater or less extent, supported on, and protected by, branched horny polypidoms. These are often exceedingly elegant in their form, and many of them are familiar to every sea-side visitor—by whom, however, they are generally regarded as sea-weeds. They consist of continuous horny tubes, generally with a jointed appearance, and bearing the little cup-like cells occupied by the individual polypes along the sides and at the extremities of the stem and branches. The cells communicate by a perforation at the bottom,



Fig. 29.—*LAOMEDREA GENICULATA*.

b, ovarian vesicles; *c*, polype extending;
d, extended polypes.

with the general tubular structure of the polypidom, which is filled with a substance apparently very analogous to that of which the polypes are composed, and serving as a sort of common bond of union between the many individual animals occupying the same stock. This common medullary pulp, as it is called, may in fact be regarded as the most important portion of the compound polype; for it is by the increase of this that the polypidom continues growing, and it appears to have the power of producing new polypes, not only in the fresh cells formed during growth, but also in those which have already been occupied, but which have been vacated by the death of their former tenants. The growth of the polypidom, according to Dr. Johnston, takes place in the following manner:—"The ripe ovule or bud discharged from its matrix settles and fixes itself to the site of its future existence by minute fibres, which pullulate from the underside; while from the opposite pole a papillary cone shoots up to a height determined by the law which regulates the peculiar habit of the species. The upward growth is then arrested, and the apex becomes enlarged and bul-

bous. The structure of this rudimentary shoot is at first apparently homogeneous, but very shortly the separation between the sheath and the interior pulp begins to be defined, and is made hourly more apparent by the pulp retreating inwards, becoming darker and more concentrated. That portion of it, in the bulbous top of the shoot, goes on to further condensation and development; and as it enlarges, so in proportion does the horny cuticle that covers it expand apace, until it has gradually evolved into one or two cells, which are still closed on all sides. The dark body of the polype is apparent through the thin and transparent parietes; and from its superior disc there are now to be seen some minute tubercles or knobs protruding, which becoming insensibly but steadily more elongated, constitute the tentacula of the polype, now nearly ready for a more active life. By an extension of development, or by a process of absorption not well understood, the top of the cell is at length opened, the polype displays its organs abroad, and begins the capture of its prey—for, unlike higher organisms, it is at this, the period of

its birth, as large and as perfect as it ever is at any subsequent period, the walls of the cell having become indurated and unyielding, and setting a limit to any further increase in bulk. The growth being thus hindered in that direction, the pulp, incessantly increased by new supplies of nutriment from the polype, is constrained and forced into its original direction; so that the extremities of the tube, which have remained soft and pliant, are pushed onwards, the downward shoot becoming a root-like fibre, and the upper continuing the polypidom, and swelling out as before, at stated intervals, into cells, for the new development of other polypes."—*Brit. Zoophytes*, p. 9.

A curious sort of circulation takes place in these creatures. It consists in the alternate ascent and descent of a fluid containing granules, within the tubular stem and branches of the polypidom, sometimes stopping just below the base of the polype, sometimes reaching to the very stomach of the creature. The cause of the motion of this fluid is still unexplained; it starts from no fixed point, and has no fixed point whence to return; there is nothing in the structure of the animals to throw any light upon the subject, and the behaviour of the current itself, under artificial circumstances, only renders its explanation still more difficult. Thus Dr. Roget says:—"If the currents be designedly obstructed in any part of the stem, those in the branches go on without interruption, and independently of the rest." The object of the circulation, however, appears, from Mr. Lister's experiments, to be exceedingly analogous to that of the circulation of the blood in the higher animals.

In these, as in all other polypes, reproduction is effected both by budding or gemmation and by ova. The former mode of propagation necessarily takes place in all the compound polypes, as the formation of these numerous societies is dependent upon a continual vegetative growth or budding of the common substance. In these the new individuals thus produced remain constantly attached to the parent stock; and the process by which this increase is effected has already been described. In the simple naked polypes the buds only continue connected with the parent until they are sufficiently mature, when they are thrown off to enjoy an independent existence. The mode of sexual reproduction varies greatly in the different families, and will be best understood when these come under consideration. We may observe here, however, that the polypes of this order are distinguished from the rest of the class by having the reproductive organs *external*; and as these are only developed at certain seasons, these zoophytes generally appear to be completely *asexual*; whilst in the two other orders the ova are produced in *internal* ovaries, and these organs are constantly present.

Divisions.—The first family, *Hydridae*, contains only a single genus (*Hydra*) of polype, some of which may be met with in almost every piece of stagnant or slowly-running fresh water. They are usually attached to some aquatic plant, and their most favourite station is amongst the rootlets of the duckweed, so common in all our ponds. The animal, when extended, consists of a long gelatinous cylinder, attached by one extremity to the sub-aquatic plant, and furnished at the other with very long tentacles, which it stretches about in the water in search of



Fig. 30.—Hydra.

the minute animals on which it feeds. In a state of contraction it presents the appearance of a mere gelatinous lump or button.

The tentacles, or feelers, are said to be tubular, and filled with an albuminous fluid. They are furnished with a variable number of tubercles, arranged in a spiral manner on the surface. These tubercles are beset with a number of spinigerous vesicles, which serve as organs of touch, in the midst of which, at the apex of the tubercle, a very singular organ of prehension is situated. Each spinigerous vesicle consists of two sacs, placed one within the other, with a small cavity in the centre of the inner one. At the point of contact of the two sacs is placed a long ciliary hair, which projects from the surface of the tentacle. The organ of prehension, which is called the *hasta*, consists of a sac opening at the surface of the tentacle, within which, at the lower portion, is placed a saucer-shaped vesicle, supporting a minute ovate body, which again bears a sharp calcareous piece called the *sagitta*, or arrow. This can be

pushed out at the pleasure of the animal, serving to roughen the surface of the tentacle, and afford a much firmer hold of its living prey. It is supposed that a poison is also ejected at the same time, as animals when seized by the hydra are observed to die almost instantaneously. Muscular bands are observed running through the substance of the tentacles; some passing from tubercle to tubercle, marking out a series of lozenge-shaped spaces, and others running in a longitudinal direction through the tentacle. Of these, the former have been regarded as *extensor* muscles, the latter as *adductors*. But the action of these muscles is apparently quite insufficient to explain the extraordinary extensibility of the tentacles, which, from a mere tubercle, may be stretched out to the length, in one species, of no less than

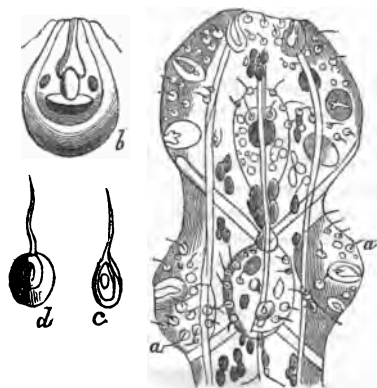


Fig. 31.—Tentacles of Hydra.
a, tubercles; b, hasta; c, d, spinigerous vesicles.

eight inches. "To produce this degree of elongation," says Dr. Johnston, "it seems necessary to have superadded the propulsive agency of a fluid. Water flows, let us say by suction, into the stomach through the oral aperture, whence it is forced by the *vis à tergo*, or drawn by capillary attraction into the canals of the tentacula, and its current outwards is sufficient to push before it the soft, yielding material of which they are composed, until at last the resistance of the living parts suffices to arrest the tiny flood; or the tube has become too fine in its bore for the admission of water attenuated to its smallest possible stream,—how inconceivably slender may indeed be imagined; but there is no thread fine enough to equal it, seeing that the tentacula of *Hydra fusca* in tension can be compared to nothing grosser than the scarce visible filament of the gossamer's web."

The most wonderful portion of the history of the Hydra consists in its extraordinary powers of propagation. The most usual mode in which reproduction takes place is by a process of budding or gemmation, in which some portion of the substance of the creature is pushed out into a small tubercle; this gradually becomes

larger, and at length develops a circle of tentacles from its upper extremity. The young animal is then complete, but generally remains attached to its parent for a short time longer, stretching out its tentacles and taking food in precisely the same manner as the old animal. Nor is it an unusual thing to behold the young one and the old one struggling for, and gorging different ends of the same worm. Before the development of tentacles on the young Hydra, and even after these have made their appearance, a communication exists between the digestive cavity of the parent and that of its offspring; so that food given to either of them produces more or less distension of the bodies of both. This communication, however, appears to close some little time before the separation of the young animal.

After the young one is thrown off there remains no mark to show whence it had been protruded. In warm weather the young Hydre are produced very rapidly, a single polype sometimes bearing about as many as four young ones, depending from various parts of the body. And no sooner is one of these thrown off than another appears to take its place; and, what is still more extraordinary, "the young ones themselves often breed others; and those others sometimes push out a third or fourth generation before the first fall off from the parent."—(*Baker*.) According to Trembley, the average number of young produced by a single *Hydra grisea*, in summer, is twenty per month; but as each of these would in a few days be surrounded by a numerous family of children and grand-children, all as prolific as itself, it may readily be imagined that the monthly progeny of one of these creatures will be exceedingly numerous.

This mode of reproduction is, however, confined to the summer months. A different provision is necessary for continuing the species from year to year. For this purpose, in autumn, the Hydre produce small bodies, which have been called *oviform granules*, and which remain like seeds in the water, until the return of spring causes them to develop a new race of polypes. Little is known of the true nature of these bodies, which are regarded by Ehrenberg as female or hermaphrodite polypes, deprived of tentacula and loaded with ova, like the female polypes, or ovigerous vesicles of the following family.

Singular as are these natural modes of increase, they are surpassed by the very curious phenomena presented by the artificial multiplication of the Hydra by the mechanical division of its substance. On this subject, Trembley of Geneva, who discovered and described the singular properties of this creature about the year 1744, speaks as follows:—"I have opened a polype on my hand, extended it, and cut the simple skin of which it is formed in every direction; I have reduced it to little pieces, and, in a manner, minced it. These little pieces of skin, both those which did and those which did not possess arms, became perfect polypes."

An operation which, to almost any other animal, would prove injurious or fatal, is thus found, in the case of the Hydra, only to assist the propagation of the species. Wounds heal up with marvellous facility; and by cutting the creatures in various directions, the most extraordinary monsters may be produced. A tail deprived of its head will produce a fresh one in four or five days; whilst the amputated head forms a new tail in about the same time. These singular facts were received, as may be supposed, at the time of their discovery, with no little incredulity; but the testimony of numerous observers leaves no room to doubt of their correctness, and the animals themselves are so common that any one may repeat the experiments of Trembley and Baker for his own satisfaction.

We have devoted so much space to the reproduction of these curious creatures, that

the remainder of their history must be dismissed in but few words. Although commonly found attached by their caudal extremity, they are capable of moving from place to place with facility, somewhat in the manner of a leech, by attaching the anterior extremity at some distance from the tail, then detaching the latter, and drawing the body up into a loop, so as to bring the tail close up to the head. This motion is then repeated; and the Hydra thus advances by a series of steps, each of the length of its body. It can also glide almost imperceptibly on its base, and not unfrequently floats, in the water, hanging from the surface by its caudal extremity.

The Hydrea are exceedingly voracious, and feed only on living animals. The larvae of insects, worms, and the minute crustaceous animals which swarm in all waters constitute their principal food. Sometimes two polypes will seize upon the same worm, when a dispute, of course, ensues, which occasionally ends in a very singular manner. If the weaker of the two does not feel inclined to let slip a booty for which he has perhaps been waiting with extended tentacles for several days, it sometimes happens that each polype swallows the end which has fallen to his share, until at length the worm being all gone, the mouths of the pair come into actual contact. They now find themselves in a position of considerable difficulty, which is sometimes terminated by the breaking of the worm; but if this does not take place, the larger or stronger of the two seizes upon his antagonist, and swallows him, worm and all. After a time the swallowed polype emerges uninjured from his living tomb; the worm, however, is gone. One of the most singular circumstances connected with the digestion of the Hydra—a digestion which, as we have seen, is capable of dissolving creatures of far higher organization than itself—is, that the creature may actually be turned inside out without any derangement of its functions; the old inner surface now acts the part of a skin, whilst that which was the outer skin adapts itself without difficulty to the performance of the work of digestion.

The polypes of the second family, the *Sertulariidae*, all live in societies, each polype being inclosed in a sort of horny cup, supported on a branched polypidom of the same consistence. The structure and mode of formation of these polypidoms, which are amongst the most elegant productions of the sea, has already been described. Their delicate arborescent forms are constantly to be seen attached to the sea-weeds left upon



Fig. 32.—Part of *Sertularia filicula*. *a*, natural size; *b*, magnified.

the beach by the retiring waves. The cups or cells containing the polypes are sometimes placed at the extremity of long stalks, sometimes arranged along the sides of the stem and branches of the polypidom; and the family has been divided into two sub-families, in accordance with these characters. The *Laomedea geniculata*, of which a figure has already been given, is an example of the former mode of growth, characteristic of the sub-family of *Campanularina*; in the second arrangement, the cells are sometimes placed

along both sides of the tubular portion of the polypidom, sometimes only in a single series along the upper or lower surface of the branches. These constitute the sub-family *Sertularina*. In some instances the stem springs from a proper root, so

that the zoophyte is isolated. In other cases the roots of the polypidom creep over the surface of the object to which it is attached, frequently covering large pieces of seaweed with a complete network of minute horny fibres, from various portions of which spring the delicate plant-like structures which support the active polypes.

Independently of the reproduction by gemmation, which is a necessary condition of their existence as compound zoophytes, the propagation of these polypes is effected by the development at certain seasons of peculiar cells, called *ovigerous vesicles* (Fig. 33), which are regarded by some zoologists as fertile polypes. They are destitute of tentacles and of digestive organs, and contain, when mature, a number of minute ova; after the discharge of these the vesicles fall off, and the zoophytes appear completely sexless. The ova, when discharged, are active, and swim freely in the water for two or three days, when they fix upon a spot for their further development, settle there, and shoot up into a polypidom similar to that from which they derived their existence. This freedom of motion in the ova, of all stationary animals, is one of the admirable provisions of nature for securing the due distribution of her productions through the world of waters; for as these polypes in their mature state are confined to a single locality, it is evident that if their ova merely dropped to the bottom of the water, more of them would be developed in a single spot than could conveniently exist there; the ova are consequently endowed with a locomotive power, enabling them to emigrate to such a distance from the parent stock, as to avoid all chance of inconvenient crowding. The



Fig. 33.—*Sertularia pinata*.
a a, ovigerous vesicles.



Fig. 34.—*Eudendrium ramosum*
(magnified).

forms of some of these active ova or germs, as described by Sir John Dalyell and Professor Van Beneden, remind one strongly of the creatures forming the next class, a circumstance which, when taken in connexion with the fact that many animals, apparently belonging to the following family, are found to be only stages in the reproduction of the *Medusa*, affords a strong argument in favour of the views of some zoologists, who remove all the polypes, belonging to the present order, into a position more in accordance with the intimate connexion which appears to exist between them and these higher *Radiata*.

The *Tubularidæ*, forming the third family of hydroid polypes, are also for the most part social animals, frequently possessing a polypidom, which, however, when present, is of a much less firm consistence than the horny framework of the *Sertularidæ*. The polypes are never entirely retractile within their tubes; the upper extremity is enlarged into a clavate head, surrounded by a variable number of tentacles.

The family is divided into two sub-families, the *Tubulariadae*, in which the polypes

are inclosed in a polypidom (Fig. 34) ; and the *Corynida*, in which they are naked, or only furnished with a rudiment of a polypidom. The genera are founded on the arrangement and form of the tentacles.

The fertile individuals, when they have been observed, are generally mere knobs, in which the tentacles are completely wanting ; and it is supposed that they derive the nourishment necessary for the performance of their reproductive functions from the active barren polypes. One mode of propagation exhibited by these animals is that of the production of what have been called by Professor Van Beneden, "free or motive buds." They are produced in little clusters of bulbs, which grow from the bases of the tentacles at certain seasons, and for a certain period, after exclusion, possess a considerable power of locomotion. Sir J. G. Dalyell, in his account of *Tubularia indivisa*, informs us that on quitting the parent the bud of this species develops some little tubercles, the rudiments of the tentacles, from its under surface, and on these, as on so many feet, move about the bottom of water. After a time it appears to select a position in which to fix its permanent abode, when "it reverses itself to the natural position, with the tentacula upwards, and is then rooted permanently by a prominence, which is the incipient stalk, originating from the under part of the head. Gradual elongation of the stalk afterwards continues to raise the head, and the formation of the zoophyte is perfected." Other ovules undergo a certain degree of development whilst still inclosed in the ovisac, and are excluded from this shelter in a form somewhat resembling that of the common Hydra. They then fix themselves, and become gradually developed into the form of the parent animal. Many polypes, apparently belonging to this family, give origin, by a process of gemmation, to young Medusæ, which again produce ova, from which similar polypes are developed. The observation of this fact has given rise to the theory of what is called the "alternation of generations,"—a theory which has been applied by its originator, Stenstrup, to several other classes of animals.

Some of these polypes attain a considerable size ; the *Corymorpha nutans*, one of the most beautiful of the group, attains a length of four inches and a-half. Of the beauty of its appearance, Messrs. Forbes and Goodsir, who discovered it in the British seas, speak in the following terms :—"When placed in a vessel of sea-water, it presented the appearance of a beautiful flower. Its head gracefully nodded (whence the appropriate specific appellation given it by Sars), bending the upper part of its stem. It waved its long tentacula to and fro at pleasure, but seemed to have no power of contracting them. It could not be regarded as by any means an apathetic animal, and its beauty excited the admiration of all who saw it." The general colour of the creature is a delicate pink, with longitudinal lines of brownish or red dots. The tentacles are very numerous and long, and of a white colour ; and the ovaries, which are situated immediately above the circle of tentacles, are orange. Most of the *Tubulariæ* inhabit the sea ; but one species, the *Cordylophora lacustris*, is found in the dock of the Grand Canal, Dublin, in water which is perfectly fresh.

ORDER II.—ASTEROIDA.

General Characters.—The asteroid polypes are all compound animals, inhabiting a polypidom, which consists of a fleshy external layer, supported upon a calcareous axis. The polypes which are imbedded in this fleshy mass are furnished with eight flat tentacles, placed in a single circle round the mouth, and not unfrequently toothed or fringed on their margins. The outer integument consists of two membranes, which are so thin on the portion of the creature which can be protruded from its cell as to permit

the internal organs to be seen through them with ease. Towards the base of the body, however, the outer of these membranes increases in thickness, and becomes continuous with the common covering of the polypidom, in which, in most of the asteroid polypes, minute particles of carbonate of lime are secreted, forming either spicula or small granulated masses, which give increased stability to the whole. The inner membrane, retaining its delicacy of texture, is continued through the cell of the polype, lining this as well as the numerous canals which penetrate in minute ramifications to all parts of the polypidom. The stomach is a distinct membranous sac or tube, commencing immediately within the mouth, occupying the centre of the cylinder formed by the outer integuments, with which it is connected by eight membranous partitions, which alternate with the bases of the tentacles, and divide the space between the walls of the stomach and the skin into eight equal compartments. These partitions are continued beyond the termination of the stomach in the form of membranous plaits or folds, between which some filamentous organs are to be seen, which have been regarded by some zoologists as the ovaries. It appears, however, that the ova are produced from



Fig. 35.—Red coral (*Corallium rubrum*).

the inner surface of the membrane lining the canals of the polype mass, and not in peculiar organs set apart for this purpose; consequently, the true office of the organs just mentioned, still remains undetermined. The stomach is perforated at its termination, so that it communicates with the internal canals; but the opening is capable of being closed by means of a circular muscle.

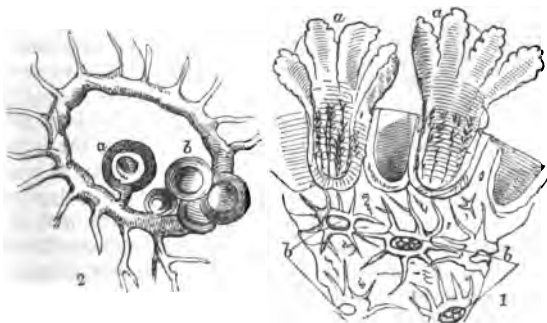


Fig. 36.—Reproduction of Aleyonium.

1. Section of Aleyonium, showing, *a a*, polypes; *b b*, canals cut across, some containing ova. 2. A canal more highly magnified. *a*, a mature egg; *b*, an ovule commencing its development.

The ova first make their appearance in the form of little tubercles, which gradually increase in height, and become narrowed at the base, until they form small seed-like

bodies, adhering by a short stalk to the membrane from which they have arisen. In process of time this stalk becomes absorbed, and the eggs are set at liberty to commence their further development. For this purpose, however, they must get out of their prison,—an undertaking not altogether unattended with difficulty. The eggs gradually work up to the base of the stomach, which, as we have already stated, is perforated with a dilatable opening; but the sphincter muscle, which acts the part of a porter at this living door, appears occasionally to entertain some doubts of the propriety of allowing the egress of the young fry, and the eggs are frequently repulsed from the opening before they are permitted to effect a passage into the stomach. From this cavity they are at last ejected into the open sea, where they swim about for a time by means of cilia, in the full enjoyment of a freedom, which, however, is soon to end.

Divisions.—This order of Zoophytes is divided into four families, from characters derived from the nature of the polypidom. In the first, this consists of a series of parallel tubes, each of which serves as a habitation. The tubes are generally of a calcareous nature, and are united together by transverse partitions. This family is called *Tubiporiæ*, from the name of its most typical genus, *Tubipora*; of this only a single species is known, the red "Organ coral" (*Tubipora musica*), inhabiting the Indian Ocean, in which the polypidom is of a deep crimson colour, contrasting strongly with the bright green of the living polypes.

In the family *Alcyonidæ*, one of the British members of which has received from

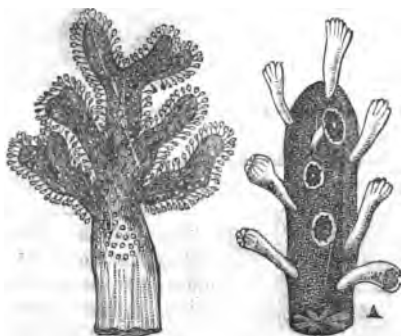


Fig. 37.—*Alcyonium*.

A, a portion enlarged, showing the polypes.

our fishermen the elegant appellations of *Cow's paps*, *Dead man's toes*, and *Dead man's fingers*, the polypidom is of a spongy nature, and contains a multitude of minute calcareous concretions which serve to give firmness to the fabric. When the polypes are contracted, the surface of the polypidom which is covered with a coriaceous skin, is seen to bear numerous scattered stellate marks, which, on examination, are found to consist of eight rays corresponding with the tentacula of the polypes which are to be protruded from these spots. The cells occupied by the polypes are placed at the terminations of canals which run through the polypidom, and which, by their union with each

other, serve to maintain a communication between the individual polypes constituting the mass. The rest of the polypidom is made up of a transparent gelatinous substance, containing the calcareous spicula above mentioned, and pervaded by numerous small fibres, which form a sort of irregular network. The *Alcyonidæ* are always attached to submarine bodies. The species already mentioned is exceedingly common round our coasts; so much so that, as Dr. Johnston says, "scarce a shell or stone can be dredged from the deep that does not serve as a support to one or more specimens." It often covers these objects with a simple crust of about an eighth of an inch in thickness, but far more frequently rises up from the surface of attachment in conical or finger-shaped

lobes, from the varied forms of which it has obtained, in the vocabularies of our maritime population, the expressive, if not very refined, names already mentioned.* One of the most remarkable species belonging to this family is the *Alcyonium poculum*, or Neptune's cup, which is found upon the coral reefs in the eastern Archipelago. The polypidom of this zoophyte, which bears some resemblance to a wine glass in form, is sometimes as much as three feet in height, and eighteen inches in diameter at the mouth.

In the *Gorgonidæ*, which constitute the third family of asteroid polypes, the calcareous matter when present, instead of being scattered in the form of granules or spicula throughout the substance of the polypidom, is collected into a solid central axis, covered by the fleshy mass in which the polypes are imbedded. The axis is sometimes calcareous, sometimes horny, and in some curious forms it consists of a mixture of both substances; as in the *Isis hippuris*, a species inhabiting the Indian seas, the axis of which is formed of a series of calcareous joints united together by horny rings (Fig. 38). Most of the species possessing a horny axis (*Gorgonia*, and allied genera) grow in a more or less arborescent form; but in some species, well known in a dried state as "sea-fans," the longitudinal branches are united at irregular intervals by a number of transverse pieces, which are composed of a continuation of the horny axis, covered with the cortical substance, and bearing polypes exactly like the main stem and branches.

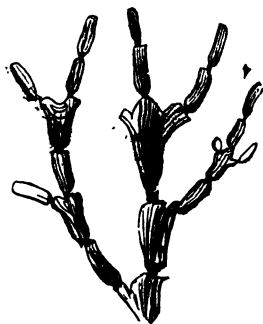


Fig. 38.—Part of axis of *Isis hippuris*.

But there is one species belonging to this family, with the stony axis of which most of us have been acquainted from our earliest years, although it is probable that many are still ignorant of its origin. This is the *Corallium rubrum* (Fig. 35), the animal which produces the common red coral, a substance of great beauty, and, at one time, of considerable value. In Persia, China, and Japan, coral ornaments are still valued as highly as gold, and large quantities of them are manufactured in Naples for the eastern markets. The zoophyte appears to be confined to the Mediterranean Sea, where it grows, especially on the southern coasts, attached to rocks at considerable depths in the sea. It is fished up from the deep by means of nets and other instruments, which, like many other things in these early homes of civilization, have undergone little or no change in their construction for many centuries. But the fishery is one of considerable importance to the countries which carry it on; and a great number of the popular tales and legends of the inhabitants of the south coast of Europe are connected with this favourite employment. So completely ignorant were the older writers of the true nature of coral, that some of them even referred it to the mineral kingdom; and even as lately as the middle of the last century, naturalists were in the habit of regarding coral as a vegetable production. This opinion was further supported by the discovery of the supposed *flowers* of the plant, by an Italian naturalist, who gave the world an exceedingly full description of their structure. So firmly had the belief in the vegetable nature of coral taken root, in the minds even of scientific men in those days, that

* The popular names of this species, the *Alcyonium digitatum*, in most countries, are derived from its fingered appearance; the French call it *Main de mer*, or "sea hand;" the Germans, *Diebshand*, or "thief's hand," and *Fingerkork*.

when a surgeon of Marseilles, who had examined the zoophyte either with more care or more judgment than his predecessors, found, to his astonishment, that the so-called flowers were really animals, endowed with the power of voluntary motion, even Reaumur, to whom he forwarded an account of his discovery, thought it advisable, when communicating it to the Academy of Sciences in Paris, to conceal the name of the discoverer, lest he should be exposed to the derision of his contemporaries—for that learned body considered the statement so exceedingly improbable that it could not be entertained for a moment.

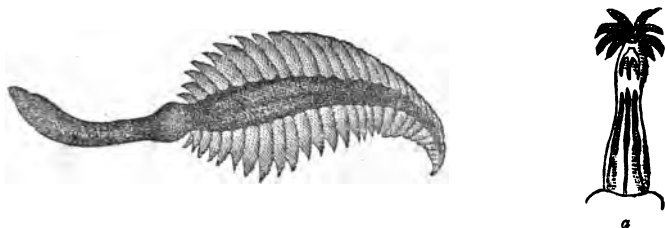


Fig. 39.—Pennatula.
a, a single polype magnified.

The zoophytes of the three preceding families all grow attached by the base to rocks or other submarine bodies; in those of the fourth family, the *Pennatulidæ*, on the contrary, the polypidom is completely unattached, and they are only retained in their proper position by the insertion of the lower portion into the sand or mud of the



Fig. 40.—Portion of *Virgularia Mirabilis*, magnified, showing the polypes.

bottom of the sea. The main stem of the polypidom of these animals is fleshy, but furnished with an internal bony axis, which, however, does not reach to either extremity of the stalk. The polypes are not situated upon this portion, but upon a series of lamellæ, which stand out upon each side of the stalk, giving the whole creature, in some cases, the appearance of a large quill-feather. It was formerly supposed that these polypes swim by the waving of the pinnae to and fro in the sea; and as some of them are most brilliantly phosphorescent, the beautiful appearance which would be presented by the motion of such a splendid undulating meteor through the water may, perhaps, be imagined. In the words of Dr. Grant, "a more singular and beautiful spectacle could scarcely be conceived than that of a deep purple *Pennatula phosphorea*, with all its delicate transparent polypi expanded, and emitting their beautiful phospho-

with all its delicate transparent polypi expanded, and emitting their beautiful phospho-

rescent light, sailing through the still and dark abyss by the regular and synchronous pulsations of the minute fringed arms of the whole polypi." But, unfortunately for this charming vision, all that we know of the habits of these creatures tends to show that, although certainly not rooted to one spot like the other polypes, they are completely sedentary in their mode of life, remaining always in one place, with the base of the central stalk buried in the soft bottom of the sea.

These zoophytes vary considerably in form. In some cases, of which the *Pennatula*, or "sea-pen" already figured, may serve as an example, the central stalk is of moderate length, whilst the pinnæ are tolerably long, giving the creature so completely the appearance of a feather, that, to use the words of Lamarck, "it seems, in fact, as if nature, in forming this compound animal, had endeavoured to copy the external form of a bird's feather." In some genera, *Virgularia* and *Pavonaria*, to which the name of "sea-rushes" has been given, the central stem is very much prolonged, some of them measuring between three and four feet in length. The polypiferous lobes are comparatively short.

ORDER III.—HELIANTHOIDA.

General Characters.—The Helianthoid polypes, of which the common sea-anemones, of our coasts, may serve as an example, approach much more closely in their structure to the Asteroid than to the Hydroid polypes. In fact, it has been proposed by some zoologists to confine the name of *polypes* to the two former orders, removing the last-mentioned group to another position amongst the Radiata. Like the Asteroid polypes, the animals forming the present order have a stomach, consisting of a sac quite distinct from the outer walls of the body; like them, also, the space between the stomach and the outer integuments is divided into cells, by membranous or muscular partitions, upon which the ova are produced. But, instead of eight flat fringed organs, the mouth is surrounded by a variable number of tubular tentacles, which are generally very numerous, and arranged in multiples either of five or six; and the lamellæ of the interparietal space follow the same rule as to number.



Fig. 41.—*Actinia Mesembryanthemum*.

Some of them, as the *Actiniae*, are free and naked; but the greater number secrete a calcareous polypidom, which, however, differs widely from that of the preceding order. Instead of the polypes being imbedded in a fleshy or leathery mass, supported on a calcareous or horny axis, the cells inhabited by the Helianthoid polypes are hollowed out immediately in the stony polypidom; the lamellæ, which divide the space between the outer skin and the stomach into compartments, being also supported by a calcareous plate; so that when the polypes are removed the cells still exhibit a radiate structure. The *Actiniae*, one of the commonest species of which is represented in the above figure, will furnish us with a very good idea of the individual polypes of this order.

These animals generally consist of a cylindrical body, truncated or cut off at the two

extremities; the lower surface, which forms a flat disc, adheres, by means of a glutinous secretion, to rocks or other submarine bodies; whilst the upper is perforated in the centre by the oral aperture, and furnished with a variable number of tentacles, which in many species are exceedingly numerous, and tinged with the most vivid and delicate colours. The skin of the sides of the animal is of a much firmer texture than that of either the oral or basal disc. At the upper edge it forms a sort of border, which completely conceals the more delicate tentacles during contraction, when the animal presents the appearance of a conical lump of flesh, with a slight impression at the apex. The stomach is a plaited membranous bag, which, when the animals are exceedingly hungry, is not unfrequently turned completely out of the oral aperture in the form of a semi-transparent bladder, constricted in various parts into lobes of greater or less extent.

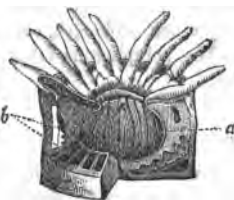


Fig. 42.—Section of Actinia.
a, cavity of stomach; b, surrounding chambers.

When the stomach is protruded in this manner, some small white filaments are often to be seen projecting from an opening at the bottom of the sac; these have been regarded as ovaries by some authors, but they seem rather to be the male generative organs. The space between the stomach and the outer walls of the body is divided into compartments by a series of muscular lamellæ, by the action of which the various changes in the form of the creature are effected. Many of these lamellæ do not reach the stomach; so that they form projecting leaflets, with a free margin, upon which the true ovaries are produced.

The extension of these animals is effected by the imbibition of water, either through the mouth or the pores of the tentacles. This fills the interparietal space, and is forced thence into the tentacles; the little pores at their tips being kept closed until every part of the creature is distended to the utmost, often presenting a most beautiful appearance. The contraction of the walls of the body, and of the perpendicular lamellæ, soon forces out this water, when the *Actinia* wishes to contract itself; the water passes off through minute pores at the tips of the tentacula; and when the contraction is sudden, it is sometimes ejected to a distance of a foot or more.

The ova of the Actiniæ, like those of other polypes, are active when first excluded. For several days they swim freely about, by means of the cilia with which they are furnished; then fix themselves, and, after passing through a series of changes, gradually assume the likeness of the parent. In the *Actiniæ* the ova are frequently hatched, if such a phrase may be allowed, within the chambers of the interparietal space; and after remaining in these cavities for some time, the young animals are ejected through the mouth. The same circumstance may probably occur in other groups of Helianthoid polypes; but these do not present themselves so readily to the continued observation of naturalists.

The polypidom of the Helianthoid zoophytes is essentially a cast in carbonate of lime of the structure of the animal. It is presented in its simplest form by the *Fungia*—a group of corals in which the polypidom is inhabited only by a single polype. In these, when the polype is very young, only a small number (generally six) of calcareous lamellæ are developed. As the animal increases in size, others are produced between those first formed; others again between these; and so on, until at length the number of these stony rays becomes quite extraordinary. The mode of formation of the compound corals is very similar to that of the *Fungia*, except that in the former the increase

of size of each polype; and, of course, also of the cell which it inhabits, is restrained within much narrower bounds,—the *Fungia* growing apparently for an indefinite period, and constantly increasing the size of their polypidom by shooting out fresh rays; so that the outline of the original cell is very soon entirely lost. The arrangement of the individual polypes, in the compound *Helianthoida*, varies in the different families, and the form of the coral varies with it.

Humble as these creatures are, their operations occupy an important place in the history of the globe. Islands—some of them of considerable size, and affording a habitation to an entire race of human beings—owe their elevation (from the bottom of the ocean, and the solidity which enables them to resist the continual action of the tremendous breakers of the tropical seas) to the labours of these apparently contemptible agents; and in the geological periods of the world's history they appear to have played even a still more important part.

Three kinds of coral-reefs are distinguished. Nearly all the shores of the seas inhabited by the reef-building corals, which occupy a broad zone extending between 20° and 30° of latitude on each side of the equator, are more or less fringed with their living walls; these are called *skirting reefs*. Other reefs are sometimes met with at a much greater distance from the shore, although still, to a certain extent, running parallel to its outlines. To these the name of *barrier reefs* has been given; the most remarkable of them is the great reef which runs along the north-east coast of Australia. The third form of reef is presented by a great number of the Polynesian islands. Many of these are of a crescent-like form, or even sometimes completely circular, inclosing, as within a wall, a basin of still water (called a *lagoon*), in which the more delicate marine animals find a welcome refuge from the tumultuous waves which rage without. These islands, which are called *atolls* or *lagoon-reefs*, are generally highest on the windward, or eastern side, against which the waves are continually dashing with great violence; the polypes, from some cause still unexplained, building with greater rapidity on that portion of the reef which is constantly exposed to the action of the breakers. On the opposite or leeward side, the reef is seldom completed; so that at this part the lagoon usually communicates with the open sea by an opening of variable width. As exposure to the air appears quickly to be fatal to these polypes, they never raise their habitations quite to the surface of the water, usually stopping at four or five feet below low-water mark. It is evident, therefore, that the living polypes can have nothing to do with the final elevation of the coral islands above the level of the sea; and we find that this is due to the action of the very waves which appear to threaten the infant island with destruction. The violence of the storm breaks off large fragments from the lower parts of the reef, and washes them up to its surface, where they rest, and gradually become agglutinated together by a constant deposit of calcareous sand, produced by the disintegration of the coral. In course of time these deposits rise above the surface,

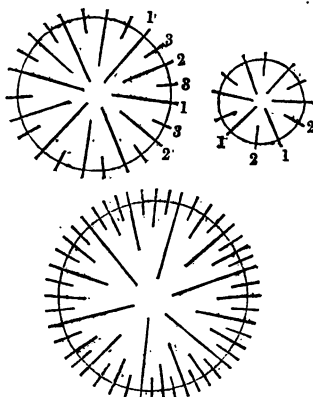


Fig. 48.—Development of *Fungia*.

when some floating cocoa-nut is thrown upon the beach, and germinates in the sandy soil. Things go on rapidly now. Birds visit the new-formed land; new species of vegetation arise; and each plant, by the decay of its fallen leaves, assists in the formation of a layer of mould in which other plants may grow. Assisted by a tropical sun and a moist atmosphere, vegetation becomes luxuriant; and the barren sandy spot, so recently raised from the bosom of the ocean, is soon converted into one of the most delightful abodes of man. The circular form assumed by these islands has led to the assumption that the coral of which their foundations are composed has been reared either upon the rim of the crater of some submerged volcano, or, when the islands are of large size, upon a ridge of elevated ground surrounding a basin, like many that may be met with upon the present earth. The principal difficulty, in the way of this supposition, is, that the polypes are found never to build or live at greater depth than from 120 to 180 feet; and it is almost impossible to imagine that the volcanoes of the continent, which is now submerged in the Pacific Ocean, were all so nearly of the same height, that their summits would come within this distance of the surface of the water. An equal or still greater difficulty presented itself in the case of the barrier reefs, to the most considerable of which we have already referred. The great barrier reef of New Holland is more than 1000 miles in length; for about 350 miles it is quite continuous; and it is evidently impossible to admit that a chain of mountains is submerged in this place with summits so very uniform in height.

To solve this difficulty, a most ingenious hypothesis has been put forward by Mr. Darwin. That gentleman considers that the observations made by him in the Pacific and Indian Oceans justify him in asserting that the whole of the bottom of these seas is undergoing considerable change of elevation; some portions of it gradually rising (areas of elevation), and others as gradually subsiding (areas of subsidence). The following diagrams will show how these suppositions serve to explain the formation of

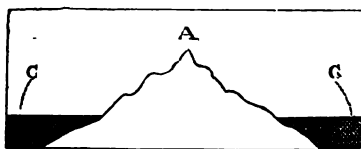


Fig. 44.

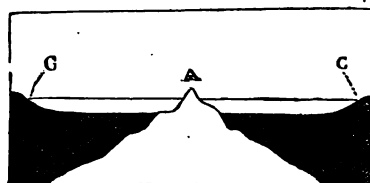


Fig. 45.

coral islands. In the first diagram, A represents the peak of an island, which may be regarded as the summit of a submerged mountain. The coral polypes, labouring in their accustomed vocation, would construct, at such a distance from the actual shore as would furnish them with a suitable depth of water, a skirting reef, C. But the island is not stationary; it is sinking very slowly; and, in process of time, we find that only a small portion of the central peak is still above the water, whilst the corals have gone on working so as to keep themselves always at the same, or nearly the same height; although the reefs which they form, instead of being only a few hundred feet from the shore of the island, are now at a distance, perhaps, of several miles. But matters go still further: the subsidence still continues; the original island disappears beneath

the waves; the deposition of *débris* upon the surface of the coral reef raises it above the surface; and it becomes a lagoon island, in the manner already described. Few things in nature, perhaps, can give us a more vivid perception of the power of that Omnipotent Creator at whose command these apparently insignificant creatures rear their stupendous edifices from the deep. Some idea of the number of architects required to produce these vast results may be obtained from the following remarks of Mr. Dana's:—

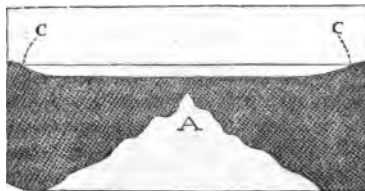


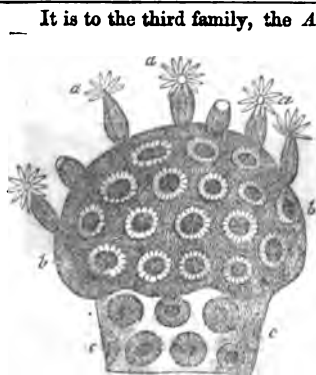
Fig. 46.

"Calculating the number of polypes that are united in a single *Astræa domè* twelve feet in diameter, each covering a square half-inch, we find it exceeding one hundred thousand; and in the *Porites* of the same dimensions, in which the animals are under a line in breadth, the number exceeds five and a-half millions. There are, consequently, five and a-half millions of mouths and stomachs to a single zoophyte, contributing together to the growth of the mass." From age to age, from the earliest periods to which the study of fossils can carry the history of our planet, to the present time, countless millions of these humble zoophytes have been ceaselessly toiling, separating calcareous matter from the waters of the ocean, and fixing it in a permanent and solid form; and immense beds of calcareous rock, in various parts of the world, bear witness to their unceasing activity, perhaps even more than the coral islands of the recent seas.

Like the greater number of radiated animals, the *Helianthoid* polypes possess urticating organs, which consist of minute capsules imbedded in the skin, containing a spicule, or a spiral thread, of great delicacy, and apparently, also, secreting an acrid fluid of some sort, which exerts a poisonous action upon any soft living tissues with which it may come in contact. The effect of this urticating power is seen in the speedy death of small fishes, and other marine creatures, which tempt their fate by straying carelessly amongst the tentacles of our common *Actinia*, several of which produce a slight sensation of heat even in the human skin. One of these, in fact, the *Anthea cereus*, is said to sting very severely.

Divisions.—In this, as in the preceding order, the characters of the families are derived from the structure of the polypidom. In the first family (the *Madreporidæ*, or "tree corals,") the polypidom is much branched, and composed of a porous substance, in which the openings of the polype cells occupy the summits of tubercular prominences of greater or less elevation. These cells are generally almost round; sometimes they are nearly superficial, but in many cases reach nearly to the centre of the coral. The rays are few in number, and rarely meet in the middle of the cell. The polypes are usually small, and possess only twelve short tentacles placed in a circle round the mouth.

The family of *Cyathophyllidæ*, or "cup corals," form polypidoms of a more or less cup-like shape, with the cell occupied by the polype at the upper extremity. The polypes are large, and furnished with many tentacles, and the rays of the cells are also numerous. This family may be divided into two sub-families, according as the cell occupied by the polype is divided or not from the lower portion of the polypidom by a transverse partition. Species of both these groups are found in deep water off the British coasts.

Fig. 47.—*Astræa viridis*

a a, expanded polypes; *bb*, polypes with drawn into their cells; *c*, coral uncovered by flesh, showing the cells.

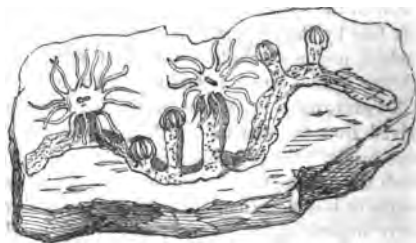
It is to the third family, the *Astræidæ*, especially that the formation of the coral reefs is to be attributed. In this the corals usually form thick stony masses; the stony rays of the cells are exceedingly numerous, and the cells themselves penetrate deeply into the mass of the coral, although they are generally partially divided by imperfect transverse partitions. Most of the zoophytes of this family appear to increase by a sort of spontaneous division, instead of by gemmation. By this means the body of the polype, and the cavity which it occupies, are in many cases not distinctly circumscribed; and the latter form curious, elongated, winding depressions in the surface of the coral. A very well known example of this form is presented by the brain coral (*Meandrina cerebriformis*).

In the fourth family, the *Fungidæ*, to which we have already referred, the polypes are single, and often attain a considerable size. The poly-

podoms form oblong or roundish masses, furnished with an extraordinary number of rays; the outermost of which project from the circumference without being confined by any outer walls. The polype occupies the whole of this radiated edifice; it is furnished with a tubular mouth in the centre, and with numerous short, round tentacles, which are scattered over the upper surface.

The family *Zoanthidæ* consists of somewhat clavate polypes, presenting a considerable resemblance in their general structure to the *Actinidæ*. They differ from these, however, in being social in their mode of life, a number of the polypes being united by a common creeping stem, which attaches them to some submarine object, and from which new polypes are produced at intervals as it runs along. The mouth is surrounded by a single row of tentacles.

We now come to the family of *Actinidæ*, or "sea anemones," the structure of which has already been described. A considerable number of these polypes occur on our own coasts; but it is in the seas of tropical latitudes that they are to be found

Fig. 48.—*Zoanthus*.

in the greatest profusion, and presenting the most beautiful appearance. Ellis, in speaking of our British species, says:—"Their tentacles being disposed in regular circles, and tinged with a variety of bright lively colours, very nearly represent the beautiful petals of some of our most elegantly fringed and radiated flowers, such as the carnation, marygold, and anemone,"—and travellers describe the beauty of the tropical species in still higher terms of admiration. Thus are the wonders of nature exhibited in her minutest productions. A race of beings, comparatively unseen and unnoticed by

the unobservant eye, presents all the beauty and perfection of mechanism which prevails in the higher orders of the animal creation ; so truly has it been observed that the wonders of the microscope fully equal, if they do not actually surpass, those of the telescope. Thus is everything, even in the very depths of the ocean, and however minute, wisely adapted to the purposes of its being. The sea anemones attain a considerable size ; some of our common British species being as large as a good-sized apple. They are far more active than the members of the preceding families, and enjoy a considerable power of locomotion. They generally adhere by the lower surface to a rock or some other submarine body ; one species, the *Actinia parasitica*, attaches itself to living crabs, and the unfortunate crustacean may often be seen in vivaria crawling about with a burden on his back nearly as big as himself. Locomotion is effected in various ways : sometimes the animals creep along almost imperceptibly upon their base ; sometimes, but more rarely, they reverse themselves, and walk along on the tips of their tentacles. Professor Forbes observed an *Actinia* "walking up the sides of a glass, by alternately adhering with its disc and base, in the leech fashion." The same distinguished naturalist met with an *Actinia*, in the Mediterranean, "which is habitually free, and swims by contractions, in the manner of a Medusa."—(Johnston, Brit. Zooph. p. 235, note.)

The tentacles are arranged either in one or several rows. In some species they are long and thin ; in others, short and thick ; in most of them the tentacles and oral disc can be retracted within the body ; but in the genus *Anthea*, of which two British species are known, they are always exerted.

The Actiniadæ are exceedingly voracious in their habits, feeding upon almost any small animals that come within their reach. Shrimps and small crabs, whelks, and even sometimes small fishes, fall a ready prey to these apparently helpless creatures. In many cases the objects taken into their capacious maw appear to bear no proportion to the original size of the animal, or to its power of prehension. Thus Mr. Cocks, of Fal-mouth, found, in the stomach of a specimen of *Anthea cœrens*, the remains of a fish four inches and a-half in length ; and in other cases he met with crabs of two inches and a quarter in diameter, in the same situation. Dr. Johnston also mentions a case which was brought to his notice, in which an individual of *Actinia crassicornis* had swallowed a valve of a scallop shell as large as a saucer. He says—"The shell, fixed within the stomach, was so placed as to divide it completely into two halves ; so that the body, stretched tensely over, had become thin and flattened like a pancake. All communication between the inferior portion of the stomach and the mouth was, of course, prevented ; yet, instead of emaciating and dying of an atrophy, the animal had availed itself of what undoubtedly had been a very untoward accident, to increase its enjoyments and its chances of double fare. A new mouth, furnished with two rows of numerous tentacula, was opened up on what had been the base, and led to the under stomach. The individual had indeed become a sort of Siamese twin, but with greater intimacy and extent in its unions." The objects swallowed as food are retained in the stomach for about twelve hours, when the indigestible matters are returned through the mouth, coated with a thick fluid, something like the white of an egg.

Although so much more complicated in their structure than the *Hydra*, whose extraordinary history has already been detailed, these animals possess a nearly equal power of surviving and repairing an amount of injury that would be fatal to most other creatures. Dr. Johnston says :—"They may be kept without food for upwards of a year ; they may be immersed in water hot enough to blister the skin, or frozen in a

mass of ice and again thawed; and they may be placed in the exhausted receiver of the air pump, without being deprived of life, or disabled from resuming their usual functions when placed in a favourable situation." The most serious mutilations appear to be equally subjects of perfect indifference to them; their tentacles may break off and new ones will soon spring up in the place of those which have been removed; the whole upper part of the body may be cut away, and after a time the base will produce a new mouth, oral disc, and tentacles, and proceed with its vital functions as if nothing had happened to disturb the even tenour of its existence. Nay, it is said that if the whole body be torn away, leaving only a portion of the base, this fragment will gradually produce a new creature. Still less does the upper portion, when amputated in this manner, lose any fraction of its vitality. On the contrary, as soon as it has recovered from the shock naturally consequent upon such unceremonious treatment, it resumes its former activity, stretching out its tentacles and capturing its prey, apparently quite unconscious that it has no stomach to put it into,—for at first all the food taken at the mouth passes out at the opposite end, "just as a man's head, being cut off, would let out at the neck the bit taken in at the mouth." The *Actinia* that has undergone the operation of decapitation has, however, one great advantage over the human subject who has been placed in the same predicament: this condition, which is irremediable in the latter case, is only temporary in the more fortunate polype; and just as the base develops a perfect oral surface in the place of that which it has lost, the latter, when left to itself, soon closes up the awkward gap in its lower regions with a new base, which retains the food in the digestive cavity, and adheres to submarine objects as firmly as its predecessor. In one recorded case, the upper half, instead of producing a new base, actually developed a second mouth, with its complement of tentacles; so that a double polype was produced, which captured its prey at both ends at the same time. If the body be nearly divided perpendicularly, the two halves will unite again in a few days; but if the section be complete, two perfect individuals are produced,—so that a process which to most animals would be fatal, is here only a means of propagation. An instance of the tenacity of life of these creatures is related by Hughes in his "Natural History of Barbadoes." After describing the occurrence in a rock-pool, on the coast of that island, of some creatures resembling the common garden marygold, which protruded themselves from holes in the rock, he says:—"Many people coming to see these strange creatures, and occasioning some inconvenience to a person through whose grounds they were obliged to pass, he resolved to destroy the objects of their curiosity; and, that he might do so effectually, caused all the holes out of which they appeared to be carefully bored and drilled with an iron instrument; so that we cannot but suppose that their bodies must have been entirely crushed to a pulp; nevertheless, they appeared in a few weeks from the very same places." "Yet these creatures," says Dr. Johnston, "almost indestructible from mutilation and injury, may be killed in a few short minutes by immersion in fresh water."

Not only do the larger fishes and Crustacea retaliate upon the Actiniæ the war which they wage with their weaker brethren, but even man in many cases finds these zoophytes most delectable articles of food. By the Abbé Diequemare, who many years ago communicated some excellent observations upon these animals to the Royal Society, they seem to have been regarded as great delicacies. "Being boiled some time in sea water," says the Abbé, "they acquire a firm and palatable consistence, and may then be eaten with any kind of sauce. They are of an inviting appearance, of a light shivering texture, and of a soft white and reddish hue. Their smell is not unlike

that of a warm crab or lobster." Mr. Gosse also bears testimony to their excellence; and an amusing account of his first culinary efforts upon them will be found in his delightful volume on the natural history of the Devonshire coast.

The *Lucernaridæ*, which form the seventh and last family, have been arranged by some authors with the Asteroid polypes, as, like these, they possess eight tentacles, or rather eight bundles of tentacles. They appear, however, to be more nearly allied to the *Actinia* than to the Asteroid polypes; and in some of their characters they approach the *Medusa*, which constitute the following class, so that in their natural position they ought probably to be approximated, as nearly as possible, to those creatures. The *Lucernaridæ*, of which several species are found on the British coasts, are campanulate animals of a gelatinous consistence, which generally adhere by a narrow stalk to sea-weeds or other floating submarine bodies. The anterior widened extremity forms an oral disc, which is either quadrangular or octangular in its form, the angles being more or less produced into pedicles, which bear numerous short, knobbed tentacles. When the disc is quadrangular, the pedicles are forked at some little distance from their base; so that there are always eight tufts of tentacles. They feed upon any minute animals that may stray into the neighbourhood of their tentacles, which, when seeking for food, are stretched out to their

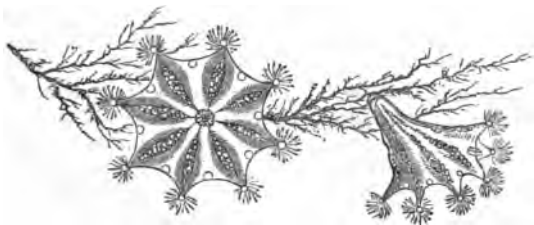


Fig. 49.—*Lucernaria auricula*, natural size.

full extent; but as soon as any unfortunate creature comes in contact with them, they seize it, and fold it into the mouth immediately. Mr. Couch says that only the tuft which has seized upon a prey is turned into the mouth, the others remaining expanded and seeking for more. Although generally stationary, these creatures are able to swim with considerable rapidity, by alternately contracting and dilating the body. When moving in this way, they continue their contortions, according to Mr. Couch, until "they meet with any obstruction, when they rest; and if the situation suits them, they fix themselves; if not, they move on in the same manner to some other spot." In moving about to short distances, as from place to place on the plant to which they are attached, they adopt the same plan as the *Hydra*, bending down their oral extremity until they can adhere by the tentacles, when "the footstalk is loosened and thrown forward, and twirled about, till it meets with a place to suit it. It is then fixed, and the tentacula are loosened, and in this way they move from one spot to another. Sometimes they move like the *Actiniae*, by a gliding motion of the stalk."—Such are the most active of the class of Polypes. We now proceed to a class of animals which enjoy freedom of motion to a much greater extent.

CLASS II.—DISCOPHORA.

General Characters.—In walking along the sea-beach, as the tide is falling, the attention of the wanderer is often attracted by the number of singular gelatinous masses left on the sands. At first sight it would never be suspected that these are really living animals, endowed with a structure of considerable complexity; but a very little exa-

mination will soon show the observer that this is the case. If one of these lumps of jelly be put into a clear pool or basin of sea-water, parts, before confounded in a shapeless mass, immediately unfold themselves; a circular umbrella-like disc, surrounded by numerous short filamentous tentacles, appears to support the creature at the surface of

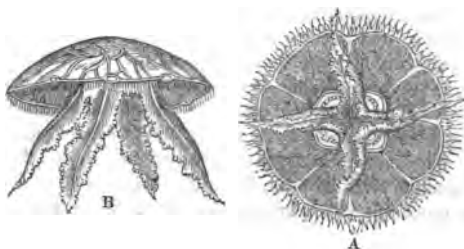


Fig. 50.—*Medusa aurita*.

A, lateral view, showing the tentacles hanging down; B, under surface.

the water; and from the centre of this hang four long arms with membranous fringed margins. This is the *Medusa aurita* (Fig. 50), the commonest Medusa of our coasts, and must have been observed by any one who has looked into the water from a boat or jetty in calm weather. In the water the creature swims along most gracefully by the alternate contraction and dilatation of its transparent disc.

All the animals of this class present a structure very similar to this. They all possess a disc of greater or less convexity, which is employed, in the manner already described, for the purposes of locomotion; and in most of them the margin of this disc is furnished with tentacles or cirri. The disc, or *umbrella*, consists of two membranes, of which the lower is called the *sub-umbrella*. In the centre of this the mouth is situated, sometimes at the extremity of a peduncle of variable length, which contains the stomach, and in some cases also the ovaries. The mouth is most frequently furnished with tentacles. Some genera, although provided with a large peduncle or with tentacles, are said to possess no mouth, the nourishment being absorbed through a number of small pores scattered upon these organs, and communicating by minute tubes with the stomach, which, as usual, is situated in the peduncle. Immediately above the stomach there is frequently a second cavity, whence a system of vessels takes its rise; these run in a radiating direction from the centre to the circumference of the sub-umbrella, where they are united by a circular vessel. In some cases these vascular canals are branched, and sometimes they form a delicate network, which runs through the whole body of the creature. When the supra-stomachal cavity is wanting, the vessels open immediately into the stomach itself. They serve to convey the products of digestion from the stomach to the various parts of the body, and at the same time expose it to the action of the water through which the animal moves. The tentacles which generally surround the mouth vary greatly in size and form; those of the margin are filiform and very variable in length. At the base the marginal tentacles (Fig. 51) terminate in a small bulb, in which the microscope reveals the existence of one or more minute cavities, which, from their structure, and supposed connexion with the faculty of hearing, have received the name of *otolitic vesicles* (*b*). They consist of an oval or roundish sac, con-

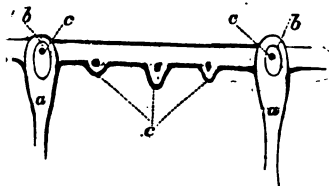


Fig. 51.—Margin of *Oceania octona*.

a, bases of marginal tentacles; *b*, otolitic vesicles; *c*, ocelli.

taining from one to nine, or even more globules. In addition to these, the bases of the marginal tentacles contain other organs, which also occur on other parts of the margin of the disc. These consist of small masses of pigment cells, each surrounding a minute silicious crystal. From the analogy of their structure they are regarded as rudimentary eyes, or at all events as organs by which a sensation analogous to vision is produced, and they have consequently received the name of *ocelli* (*c*). In many species they are present in great numbers; and in the more highly organized forms they are more complicated in their structure, and protected from injury by membranous hoods or coverings. Nevertheless, although the visual and auditory functions of these curious organs seem to be admitted on all sides, the existence of any approach to a nervous system in these creatures is still a matter of great doubt; so that if the *ocelli* and otolithic vesicles really perform the parts assigned to them, the perceptions conveyed by them to the animal must be of an exceedingly imperfect nature.

The stinging power, which has already been referred to as common to several groups of radiate animals, is possessed by many *Medusæ* in the highest perfection. The urticating organs in *Pelagia noctiluca*, as described by Professor Wagner, are placed in warts or tubercles on the skin of the animal. These warts contain aggregations of small red pigment granules, amongst which there are numerous little round vesicles, the largest being about $\frac{1}{100}$ line in diameter. Within these little capsules a spiral thread is to be seen, which bursts out of its case on the slightest pressure; these barbed capsules are always found in the urticating mucus exuded in such quantities by the *Medusæ*, to which they are considered to communicate this property. One or two, at least, of our British species sting most severely, although others are perfectly harmless. Of the *Cyanea capillata*—a species common on the British coast—Professor Forbes speaks as follows:—"The *Cyanea capillata* of our seas is a most formidable creature, and the terror of tender-skinned bathers. With its broad, tawny, festooned and scalloped disc, often a full foot, or even more across, it flaps its way through the yielding waters, and drags after it a long train of riband-like arms and seemingly interminable tails, marking its course when the body is far away from us. Once tangled in its trailing 'hair,' the unfortunate who has recklessly ventured across the graceful monster's path too soon writhes in prickly torture. Every struggle but binds the poisonous threads more firmly round his body, and then there is no escape; for when the winder of the fatal net finds his course impeded by the terrified human wrestling in its coils, he, seeking no combat with the mightier biped, casts loose his envenomed arms and swims away. The amputated weapons, severed from their parent body, vent vengeance on the cause of their destruction, and sting as fiercely as if their original proprietor itself gave the word of attack." This is a large species; most of the smaller ones appear to possess no urticating power, at least none capable of making an impression upon the human skin, although the Abbé Dicoquemare "has stated that certain species of *Oceania* sting, though very slightly, and only when they come in contact with very sensitive parts, such as the eyes." Most of our readers will probably follow Professor Forbes' example in refraining from the repetition of the worthy Abbé's experiment, preferring "keeping their eyes intact to poking *Medusæ* into them." It is from this stinging power that the *Medusæ* have received the name of "sea nettles," which appears to have been applied to them in all ages and in all languages. The ancient Greeks called them *Ακαληφαι*, or nettles—a name which was adopted into modern scientific language to designate the class of animals to which the *Medusæ* belonged.

The class *Acalephæ*, of authors, includes not only the animals of the present class,

but also those of the two following ; and the whole present so few characters in common, that Eschscholtz, in his work upon this department of the animal kingdom, was obliged to confess that the *Acalephæ* could only be described as radiated animals, furnished with distinct organs of nutrition and motion. We have, accordingly, preferred following the example of some recent zoologists, who have abolished the class *Acalephæ* altogether, and raised the three orders into which those animals were divided to the rank of distinct classes. The phosphorescence of the *Medusæ* has already been alluded to ; and we shall not, therefore, recur to it in this place.

But the most singular incidents in the biography of the *Medusæ* are the circumstances connected with their reproduction. They are all propagated by eggs, which the females (for these animals are unisexual) produce in glandular organs, sometimes arranged in bands or patches on the surface of the sub-umbrella, and sometimes in cavities at the base of the peduncle. But these ova, when excluded from the body of the parent, develop an animal quite different in form from that from which they sprang ; and it is only in the second generation that the original *Medusa* is reproduced. The eggs are developed, to a certain extent, in small pouches, placed beneath the body, and in the arms of the mother, whence they are not excluded until they have acquired the form of an active infusory animalcule (*a* in the annexed figure), furnished with cilia, enabling them to swim freely in the water. After a time, the little animal attaches itself by one extremity in some suitable position (*b*), and awaits its further development.

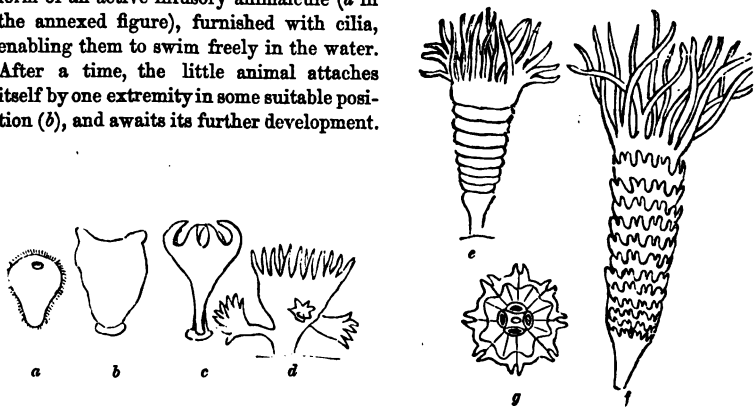


Fig. 52.—Development of Medusa.

Arms are soon formed at its upper extremity (*c*), and it now presents the appearance and takes its food in the manner of a Hydraform polype. At this stage of its growth buds are often produced, just as in a true Hydra (*d*). The body now increases considerably in length, and becomes constricted, or divided by wrinkles of the surface into numerous segments (*e*) ; these become more and more distinct, their edges become notched, and at length the animal resembles a pile of jagged saucers placed one upon another, and surmounted by a crown of tentacles (*f*). At length these separate (*g*), and swim about like little *Medusæ* ; and, after undergoing some changes, they acquire the form and colouring of the common *Medusa aurita* of our coasts. So completely do what for want of a better term we must call the preparatory states of these animals, resemble Hydroid polypes, that their connexion with the *Medusæ* has only been quite recently discovered ; and the species just referred to has been described under the name of *Hydra*

tuba. Amongst the smaller *Medusæ*, a somewhat different mode, or rather a modification of the former method of reproduction, prevails. In these, as in the larger species, the ova, when excluded, produce polypes, from which animals resembling the parent arise by a process of germination; but instead of the young *Medusæ* being produced by the division of the whole substance of the polype into a series of superposed cups, they spring from its body like true buds, which gradually become perfect Medusi-form animals (Fig. 53). They stand in much the same relation to the polype stock, from which they are produced, as the flower to its parent plant; and if we imagine a plant in which the flowers, when fully formed, are cast off to perfect their seed, whilst floating in the medium which surrounds them, we shall obtain a very good idea of the mode of development of these small *Medusæ*. The polype-stages of these animals resemble the

Tubularian and Sertularian polypes. From these circumstances, some zoologists have proposed the removal of the whole of the Hydroid polypes into the present class, of which many of them are certainly only stages of development. Opinions are still so much divided, however, as to the true affinities of these animals, that we have preferred leaving the Hydroid polypes in their old position to placing them where few of our readers would think of looking for them.

These facts have led to the establishment of the theory of the "alternation of generations." Steenstrup, who was the first naturalist to put forward this idea, as a "*general fact dependent on a law*," defines it as follows:—"The fundamental idea expressed by the words *Alternation of generations*," is "the remarkable and till now inexplicable phenomenon of an animal producing an offspring, which at no time resembles its parent; but which, on the other hand, itself brings forth a progeny which returns in its form and nature to the parent animal, so that the maternal animal does not meet with its resemblance in its own brood, but in its descendants of the second, third, or fourth degree of generation. And this always takes place in the different animals which exhibit the phenomena in a *determinate* generation, or with the intervention of a *determinate* number of generations. This remarkable *precedence* of one or more generations, whose function it is, as it were, to prepare the way for the later succeeding generation of animals destined to attain a higher degree of perfection, and which are developed into the form of the mother, and propagate the species by means of ova, can, I believe, be demonstrated in not a few instances in the animal kingdom."

Whilst admitting the general correctness of these ideas, which he considers have "given a strong impulse in the right direction to Invertebrate Zoology," Professor

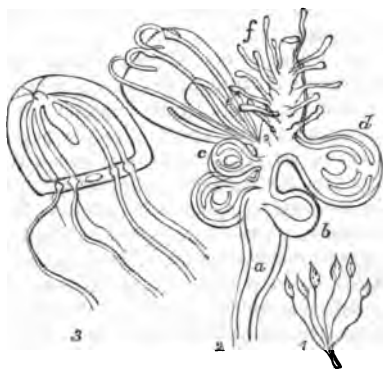


Fig. 53.—Development of *Sarsia*.

1. Polypes described as *Syncooryne*, natural size.
2. A polype, magnified. *a*, polype stem; *b c d e*, medusoid buds, in various stages; *f*, tentacles of the polype.
3. Free Medusa of the genus *Sarsia*.

Forbes says, "the assumption of definite regularity in the alternations is a secondary and non-essential one, and true, probably, when disturbing conditions are not at work. But numerous observations . . . show that under peculiar circumstances, in what may be called unnatural situations, the polype generations may go on continually producing polype generations; and those of Sars and myself, on the other hand; that a Medusa generation may go on producing Medusa generations; although, under normal conditions in each instance, there is every reason to suppose that zoophytic and Medusa forms would have regularly alternated." At least four British species of Medusæ (two of *Lizzia* and two of *Sarsia*) have the power of producing young animals by direct gemmation, and their development from a zoophytic form has not yet been observed. In *Lizzia* and *Sarsia gemmifera* the buds are produced from the stomachal peduncles; but in the other species of *Sarsia* (*S. prolifera*) they originate from the bulbs at the base of the tentacles, where they may be seen attached in all stages of development. "What strange and wondrous changes!" says Professor Forbes, after detailing his observations upon the last-mentioned minute Medusa. "Fancy an elephant, with a number of little elephants sprouting from his shoulders and thighs, bunches of tusked monsters hanging, epaulette-fashion, from his flanks, in every stage of advancement! Here a



Fig. 54.—Development of *Sarsia*.

1. *Sarsia gemmifera*. a, the peduncle, with buds in various stages of development. 2. The base of the tentacle of *Sarsia prolifera*. a, tentacle; b, ocellus; c c c, young buds; d, a nearly mature bud.

seems grotesque and absurd; but it really expresses what we have been describing as actually occurring among our naked-eyed Medusæ. It is true that the latter are minute; but wonders are not the less wonderful for being packed into small compass."

Wonderfully beautiful as are these creatures in form and colour, the amount of solid matter contained in their tissues is incredibly small. The greater part of their substance appears to consist of a fluid, differing little, if at all, from the sea-water in which the animal swims; and when this is drained away, so extreme is the tenuity of the membranes which contained it, that the dried residue of a "jelly fish," weighing two pounds, which was examined by Professor Owen, weighed only thirty grains. Yet these creatures are capable of executing movements with considerable vivacity,—their disc contracts and dilates alternately by the action of a band of what must be regarded as a muscular tissue,—their tentacles are capable of seizing upon and destroying, by a subtle venom, animals of far more complicated structure than themselves, and their delicate stomachs have the power of speedily digesting the victim. In fact,

in spite of the extreme delicacy of their texture, the Medusæ are amongst the most voracious inhabitants of the ocean. Small fishes, and Crustacea, and all the infinite multitude of minute marine creatures, are seized and paralyzed by their deadly arms; and as the mouth and stomach are capable of almost indefinite dilatation, the size of their prey often appears exceedingly disproportionate. Of the voracity of one of the most delicate and beautiful of the small Medusæ inhabiting the British shores, the *Sarsia tubulosa*, a little creature of the size and shape of a very small child's thimble, Professor Forbes speaks of as follows:—"Being kept in a jar of salt water with small Crustacea, they devoured these animals, so much more highly organized than themselves, voraciously; apparently enjoying the destruction of the unfortunate members of the upper classes with a truly democratic relish. One of them even attacked and commenced the swallowing of a *Lixia octopunctata*, quite as good a Medusa as itself. An animal which can pout out its mouth twice the length of its body, and stretch its stomach to corresponding dimensions, must, indeed, be 'a triton among the minnows,' and a very terrific one too." Mr. Peach has described, in the "Annals of Natural History," a case in which a specimen of *Thaumantias lucifera* had seized the head of a *Sagitta*, a very active molluscous animal, and suffered itself to be turned completely inside out rather than let go its hold.

Divisions.—Much still remains to be done to the subordinate classification of these animals. Prof. Forbes divides the Medusæ into two great divisions, which we shall adopt as orders. In the first of these, the ocelli, or eye-like spots, surrounding the margin of the disc are naked (Fig. 55, 1); whilst in the others these organs are protected by more or less complicated membranous hoods or lobed coverings (Fig. 55, 2). Hence the former are called *Gymnophthalmata* (or naked-eyed), the latter *Steganophthalmata* (or covered-eyed). In the former the ocelli, when present, are always placed on the bulbs at the base of the tentacles, and frequently also on the interstices between these. In the second group, on the contrary, they are always placed between the marginal tentacles.

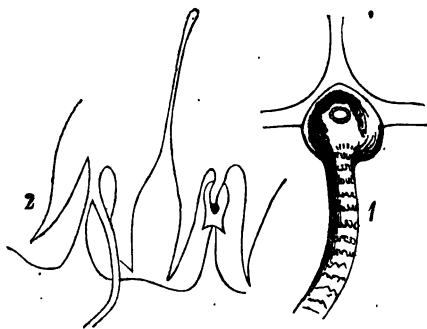


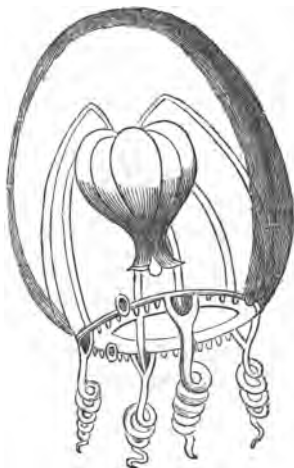
Fig. 55.—Ocelli of Medusæ.

1. *Sarsia tubulosa*. 2. *Pelagia panopyra*.

ORDER I.—GYMNOPTHALMATA.

General Characters.—In addition to the simplicity in the structure of the ocelli, we find that it is characterized by a similar simplicity in the arrangement of the vascular system. The vessels running from the stomach to the margin of the disc are either perfectly simple, forming so many straight bands, dividing the body of the animal into from four to eight perpendicular segments, or merely branched at some distance from their origin; each branch, however, running directly to the margin without uniting in any way with its fellows. The disc in some species is considerably depressed; in

others, and indeed in the majority, it is more globular, or even somewhat cylindrical in its form. The tentacles and ocelli are often very numerous, although no more than four of each exist in some species.



56.—*Modeeria formosa*.

is placed between each pair. The *Modeeria formosa*, of which we have given a figure, is one of the most charming of these charming little creatures.

In the second family, the *Geryonidae*, the vessels are also simple and four in number; but the ovaries, of which there are also four, instead of being imbedded in the peduncle are placed in the course of the vessels on the sub-umbrella. The tentacles vary greatly in number. In some species there are only four of these organs, each bearing an ocellus; in others the number of both organs is increased, until in the *Thaumantias pilosella*, of which a magnified figure is here given, there are about a hundred principal extensible tentacles, springing from ocelliferous bulbs; whilst in each of the intervals between these, six or seven shorter fibres or secondary tentacles are placed. Different species of *Thaumantias* are most important agents in producing the luminosity of the European seas.



Fig. 57.—*Thaumantias pilosella*.

The third family, *Circeidae*, includes only a single genus, of which the few species are scattered over very distant parts of the world. One is found on the coast of Kamtschatka, two on the African coasts, and a fourth has been discovered by Professor Forbes off the Shetland Isles. In this there are eight radiating vessels, and eight small ovaries placed on the sub-umbrella in the course of the vessels.

In the *Æguriæ*, amongst which are included some of the largest species of naked-eyed Medusæ, the vessels are simple and generally numerous (never less than eight); and the ovaries are linear, and placed on the course of the vessels on the sub-umbrella. Two British species of this family are described and figured by Professor Forbes; but the species are more numerous in warmer latitudes.

The Medusæ, composing the fifth family (the *Oceanidæ*, Fig. 58), are amongst the most delicate and beautiful of the class. They consist of a little conical or globular glassy body, within which a variously coloured peduncle may be seen. The lower margin is fringed with tentacles which vary greatly both in number and colour. They possess four simple vessels; and the ovaries are placed in the upper part of the stomachal peduncle, in the form of convoluted membranous tubes, which render themselves noticeable through the clear substance of the animal by their brilliant colour. In *Turris*, one of the genera of this family, the tentacles are exceedingly numerous; whilst in another genus (*Saphenia*), their number is reduced to two.

The sixth family, *Willisidæ*, is distinguished from all the rest by the branched form of the radiating vessels. These are six in number. After running some little distance from the centre of the sub-umbrella, they fork; and each of the branches again forks before reaching the margin; so that the marginal vessel receives the terminations of twenty-four radiating vessels. From the point of junction of each of these, a tentacle takes its rise. There are six ovaries placed round the base of the stomach.



Fig. 58.
Oceania episcopalis.

ORDER II.—STEGANOPHTHALMATA.

General Characters.—The Medusæ of this order are distinguished from those belonging to the preceding by several other characters besides those already described. The vessels, instead of running straight from the centre to the circumference of the disc, are variously branched, and their branches unite, more or less, with each other before reaching the margin. The margin of the disc is divided into eight principal segments by a similar number of notches, in each of which an ocellus is placed. The intervals between these notches are also frequently notched once, twice, or even more frequently; and from these points the tentacles generally take their rise. The generative organs are attached to the base of the peduncle, where this exists, or placed around the base of central tentacles where the peduncle is wanting. But few observations have been made upon the development of these animals; those whose progress has been traced are found to be produced by the spontaneous transverse division of a Hydraform polype, which itself has arisen from the egg of the parent Medusa (Fig. 52, p. 252). Many of these animals attain a gigantic stature, when compared with the minute and delicate creatures of the preceding order; the *Rhizostoma Cuvieri*, a British species, measuring two feet, or even more, in diameter; whilst some of the inhabitants of tropical seas are said to attain a still larger size. In calm weather they often swim, close to the surface of the sea, in such multitudes as to impede the motion of a boat through the water. Such a fleet as this, seen with the sun shining strongly upon them, is a magnificent

spectacle, from the beautiful iridescence with which the sunlight is reflected to the eye of the beholder. With the approach of night this scene of beauty only gives place to another; for these Medusæ are as luminous in the dark as their smaller brethren.

Divisions.—This order includes two families. The *Medusidae* have a central mouth, surrounded by four tentacles, and the remainder of their organs arranged in fours, or multiples of four. The margin of the disc is also generally furnished with tentacles. Several of these inhabit the British seas. The *Medusa aurita*, already figured (p. 250), the *Pelagia cyanella*, of which the annexed (Fig. 59)



Fig. 59.—*Pelagia cyanella*.



Fig. 60.—*Rhizostoma*.

is a representation, and the *Gyanea capillata*, the account of whose urticating powers we have given in the words of Professor Forbes, may serve as examples.

In the second family, the *Rhizostomidae*, there is no apparent mouth, and the animal is said to derive its nourishment by a species of absorption through numerous minute canals which permeate the stomachal peduncle and tentacles. The latter are usually branched, so as to be apparently rather numerous at the extremities. The margin is never furnished with tentacles. One species of this family, the *Rhizostoma Cuvieri* (Fig. 60), is found on the British coasts.

CLASS III.—CTENOPHORA.

General Characters.—We now come to a class of animals, the real nature of which is still to be made out. They are gelatinous transparent creatures, generally of an oval form, enabled to swim freely by the action of variously arranged rows of cilia. The body of these animals has so much more of the bilateral than of the radiate type in the arrangement of its parts, that their place amongst the Radiata has been disputed; and M. Vogt has placed them in the neighbourhood of the *Bryozoa*, or Molluscoid Zoophytes, as low forms of Mollusca. The radiate arrangement of the bands of cilia in most cases, and still more the presence of urticating organs in the tentacles, may justify our retaining them for the present in this position.

The cilia in the bands are arranged in transverse lines, and the cilia of each line are frequently united at the base, so as to form minute lobes, which are moved rapidly to and fro, and thus enable the creature to swim backwards and forwards, or in any other direction, at pleasure. Numerous and minute as these organs are, each of them appears

to be individually under the control of the animal. When in action they produce the most beautiful iridescent coloura, so that it is easy to detect the means by which the creature varies its course,—now paddling with one, and now with another, of its mimic wheels. The mouth leads sometimes immediately, sometimes through a narrow canal, into a large stomach, which opens again into a funnel-shaped cavity at the opposite extremity of the axis of the body. In the neighbourhood of the mouth there is generally a pair of very long, branched tentacles, capable, however, of being contracted to an extraordinary extent; these, when contracted, are usually received into a pair of cavities or sheathes, placed close to the stomach, where they lie coiled up, until again wanted for the capture of prey. The rudiment of a nervous system, consisting of a single ganglion, giving off a few branches in various directions, is said to exist in these animals; and a sort of vascular system, apparently for the conveyance of water, rising from the anal funnel, runs along the course of the bands of cilia. The vessels are lined with a ciliated epithelium, and are probably to be regarded as respiratory organs. The mode of reproduction of the *Ctenophora* is still enveloped in mystery. They are supposed to be hermaphrodites, and ova have been found in the neighbourhood of the aquiferous vessels; but where these are produced is not yet ascertained. These singular animals form but one order, which is divided into two families.

The *Beroidea*, which form the first family, may almost be said to possess no true stomach, the body being so formed as to inclose a great cavity, of which the hinder portion serves as a digestive organ. When the animals have much food in this cavity, they constrict the middle of the body so as to prevent

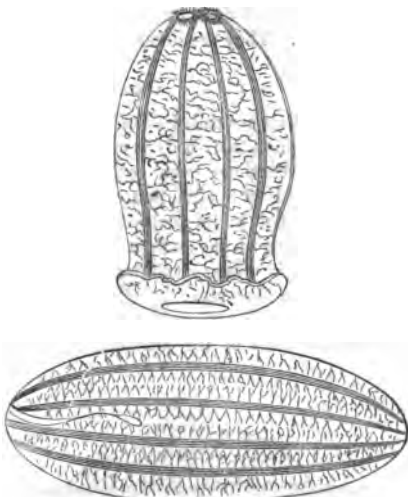


Fig. 61.—*Bero Punctata*.

any of it from escaping. The body is oval or roundish, with eight rows of cilia running from end to end of the body (Fig. 61). The mouth is large, and opens and shuts with facility; it is generally held open when the creature is in motion. The tentacles are wanting in this family.

The *Callianiridae* are distinguished from the preceding family by the small size of the stomach and mouth, and by its possession of filamentous tentacles. The little *Cydippe*, already figured (p. 228, Fig. 28), which is common in the British seas, is a good example of this group. The most singular of these animals is the *Cestum Veneris*, or girdle of Venus (Fig. 62), which inhabits the Mediterranean, and which at first sight would be

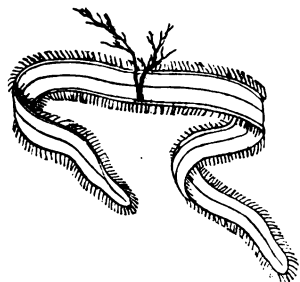


Fig. 62.—*Cestum Veneris*.

Venus (Fig. 62), which inhabits the Mediterranean, and which at first sight would be

taken for anything rather than a near relation of the little globular *Cydlippe*. In this curious creature the sides of the body are produced into a long ribbon, which sometimes attains the length of four or five feet; the mouth and digestive organs being, however, confined to their original position in the middle of the body. This animal is one of the most beautiful inhabitants of the ocean. When in motion its waving cilia, which are placed along all the margins of the body, glitter with all the tints of the rainbow; and at night it appears like a long waving flame in the water.

CLASS IV.—SIPHONOPHORA.

The *Siphonophora* form another group of animals, of which we have still much to learn before their true nature and relations can be ascertained; and it is probable that, as our knowledge of them increases, it will be found impossible to include them all in the same class. They are divided into two orders—the *Chondrograda* and *Physograda*.

ORDER I.—CHONDROGRADA.

These animals are called *Chondrograda* from the circumstance that the circular or oval disc, of which their body is composed, is supported upon a somewhat cartilaginous plate, which sometimes even contains a calcareous deposit; the lower surface of this disc is furnished with cirri, many of which are tubular. The cartilaginous plate is somewhat cellular in its texture, and the cells are filled with air, which assists the animal in floating on the surface of the water. In the middle of the lower surface of the disc there is a larger tubular, tentacle-like organ, which has been taken for the mouth by some observers; by others, for the orifice of the aquiferous system. This central opening is surrounded by many smaller ones, the offices of which are as uncertain as those of the principal tube. Many of these creatures are exceedingly

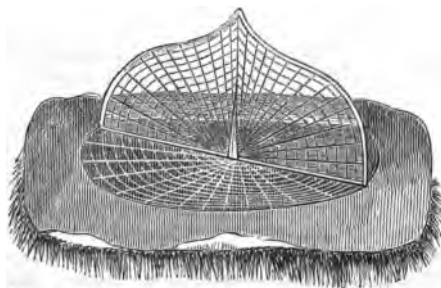


Fig. 63.—Velella.

beautiful, blue being their prevailing colour. In *Porpita*, one species of which is found in the Mediterranean, the disc is surrounded by a beautiful fringe of tentacles; but the most remarkable structure is presented by the *Velella* (Fig. 63), in which an oblique upright crest is developed upon the upper surface of the disc, serving as a sort of sail to waft the little mariner from place to place. One species of this genus is found on the coasts of Ireland.

ORDER II.—PHYSOGRADA.

The characteristic of the animals forming this order is, that they are furnished with a vesicular organ containing air, which serves as a float to buoy them up in the water. They are divided into two families. In the first, the *Physaliæ*, the animals are composed of large vesicular gelatinous bodies, bearing on their lower surface a quantity of vermiform tentacles and suckers, intermixed with filiform tentacles of great length.

The float consists of two bladders, placed one within the other; the inner one is completely closed, and filled with air; the outer possesses a crest at its upper part, which serves, like the sail of Velella, for its propulsion whilst floating at the surface of the water. The tentacles can also be retracted within this outer bladder at the pleasure of the animal. The best known of these animals is the *Physalia atlantica*, which has received from our sailors the name of the Portuguese Man-of-War. They swim in great crowds at the surface of the water, and possess a very strong urticating power.

The animals forming the second family, the *Diphyidæ*, are compound creatures, whose structure has always been a fertile source of discussion amongst naturalists. They have recently formed the subject of several excellent papers from the pen of Mr. Huxley, who considers them to be nearly allied to the common fresh-water polype (*Hydra*), whose singular history has already been described. In their simplest form they consist of two transparent pieces, one or both of which contains a cavity, by the contraction of which they are propelled through the water. The union between these pieces is very slight; and, when detached, each piece moves independently for a considerable time. From this circumstance they have been regarded as two distinct animals, which, however, are always found inserted into the cavity of the other. They have been divided into numerous genera; the characters of which are principally derived from the form of the component pieces. They frequently, however, assume a much more complicated appearance. The larger or including individual produces, from the bottom of its cavity, a slender stalk, which is continually increasing in length, and from which new polypes are produced at the portion nearest the original polype. In this manner a chain of polypes is formed, each presenting a considerable resemblance to its original parent, and each also exerting a certain degree of independent movement; although the superior power of the large parent animal always determines the direction in which the whole mass shall move through the water. In some of these animals (as *Stephanomia*), the complication becomes most extraordinary; but it would be impossible, in our confined space, to give an intelligible description of the varied and wonderful forms of these animals, which are to be met with in most seas, although they are most abundant in those of warm climates.



Fig. 64.—Diphyes.

CLASS V.—ECHINODERMATA.

General Characters.—The *Echinodermata*, the fifth and highest class of animals included by naturalists in the Radiate division, exhibit a considerable advance in complexity of structure over the simple gelatinous creatures which we have hitherto had under consideration. They are at once distinguished from these by the structure of their skin, which, instead of the delicate membranous texture, so characteristic of the other *Radiata*, presents a more or less leathery consistency, and always contains a larger or smaller amount of a calcareous deposit, which frequently increases to such an extent as to form a complete shell or crust inclosing all the soft parts of the animal. The skin is also destitute of the curious urticating organs (thread cells) which are so constantly present in all the other animals of this division. The amount of the calca-

reous deposit in the skin varies greatly in the different animals composing the class. In some (as the *Holothurie*) it forms small irregular grains, scattered, not very plentifully, through the substance of the skin; in others, as the *Star-fishes* (*Stellerida*), it constitutes plates of various forms, fitting closely to one another, but only connected by the agency of the true skin; so that although the body is completely encased in a suit of calcareous armour, every part of it still retains considerable flexibility. In others again, as the *Sea-eggs* or *Sea-urchins* (*Echinida*), these plates are positively united together, forming a continuous shell, within which all the organs of the animal are inclosed. Upon most of these calcareous plates tubercles are to be seen, which serve for the articulation of moveable spines, often of considerable size. These assist the animal in its motions; and it is from their almost universal presence that the name of the class (*Echinodermata*,—*echinos* a spine, and *derma* skin) is derived.

In their form the *Echinodermata* vary greatly. They generally present a *radiate* arrangement of their parts, with great distinctness; some, of which the well-known *Star-fish* of our coasts may be taken as an example, actually assuming the form of star. In the globular *Sea-eggs*, also, the same stellate structure may be observed; but it appears to be almost lost in the worm-like *Holothurie* (Fig 71), in which, however, the tentacular crown, surrounding the anterior extremity, still presents a radiate appearance.

The organs of motion are very similar throughout the class; they consist of a multitude of minute feet, called *ambulacra*, which are protruded through a number of perforations left for this purpose in particular plates (hence called *ambulacral plates*), or through the interstices of the calcareous pieces composing the covering of the animal. The structure of these minute organs is very interesting. In their most perfect form they are vermiform tubes, furnished at their extremity with a distinct sucking disc, which is stretched to its proper form by a small calcareous ring. The tube communicates through its aperture with a small vesicle containing fluid, situated within the shell; and it is by the contraction of this, and the consequent propulsion of the fluid into the cavity of the tube, that the extension of the *ambulacrum* is effected.

The walls of these little feet are all composed of two muscular coats, an inner longitudinal and an outer circular one; and it is by the action of these that the *ambulacra* are enabled to move about in the water in search of some object to which to attach themselves. The longitudinal muscular coat also serves to contract the organ as soon as the relaxation of the vesicle allows the fluid to flow back from the cavity of the tube, when, if the terminal suckers are attached to any fixed object, the body of the animal is of course drawn in the direction of the contraction. The combined action of a number of *ambulacra* is, however, necessary to move an animal of a size so out of all proportion to its diminutive legs as an ordinary *Star-fish* or *Sea-egg*. One of these creatures in motion is a most interesting sight. The little suckers are extended in every direction, often to such an extent that they appear only like thin semi-transparent hairs. At length one fixes, then another and another, until at last a number of them, all contracting together, drag their unwieldy owner a step forward. By means of these organs both the *Star-fishes* and the *Urchins* can creep up the surface of glass with great facility; and so firmly do they adhere, that the animal may be broken away, leaving his limbs sticking to the glass.

The existence of a nervous system in the *Echinodermata* is generally admitted by zoologists. It is said to consist of a series of ganglia, or knots of nervous matter surrounding the oesophagus, united by a nervous ring, and giving off a set of nerves to

each ray of the body (Fig 2). The presence of special organs of sense is very doubtful. The sense of touch is evidently exercised by the ambulacra, which are also employed in seizing prey. Some red spots, which occur at the extremities of the arms of Star-fishes, and on the upper surface of Sea-eggs, have been called *eyes* by some observers, but apparently with but little ground.

In their digestive organs the *Echinodermata* exhibit a very decided superiority over the other *Radiata*. They all possess a distinct intestinal canal, generally with two openings, one for the reception of food, the other for the discharge of faecal matter. The relative position of these apertures varies greatly in the different groups. In the worm-like forms (*Holothurie*), and some Sea-urchins, they are placed at opposite extremities of the axis of the body; in the other groups both open on the lower surface. The arrangement of the intestine is also subject to great variation. In the *Holothurie* it is bent twice upon itself into a form somewhat resembling the letter S; in the Star-

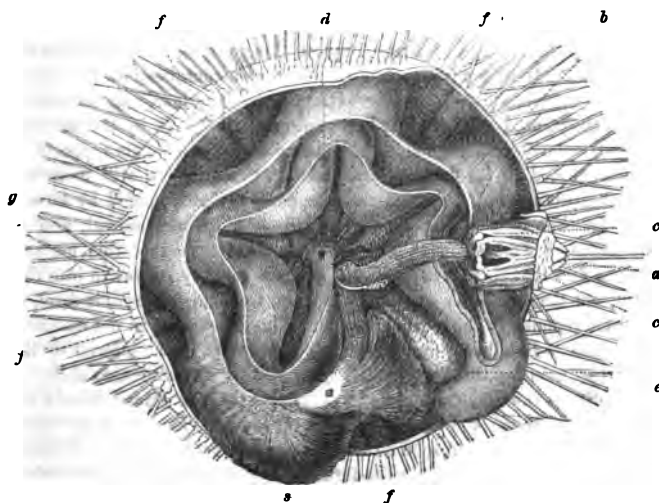


Fig. 65.—Anatomy of *Echinus*. *a*, mouth, surrounded by the teeth and jaws, *c, c*; *b*, oesophagus; *s*, stomach, or first portion of the intestine; *d*, intestinal tube; *e*, ovary; *f, f*, ambulacral vesicles; *g, g*, shell.

fishes the mouth opens directly into a large stomach, surrounded with smaller sacs, which are often branched, and in some cases extend far into the arms; whilst in the Sea-eggs the intestine is very long, and wound round in the body (Fig. 65). Some of the latter animals are furnished with an exceedingly complicated masticating apparatus, which has often been described under the name of the "lantern of Aristotle." It consists of a curious framework of V-shaped calcareous pieces, bearing, at their anterior extremity, five hard triangular teeth. The animals possessing this apparatus feed principally upon vegetable matter, whilst those which are destitute of masticating organs derive most of their nourishment from minute *Crustacea* and the other marine animals of which the shells are often found in great numbers in their intestines.

All the *Echinodermata* are furnished with very distinct organs of circulation, con-

sisting of a heart or corresponding organ, and a complicated system of vessels. Respiration is effected, in some cases, by means of branchiæ; in others, by the introduction of water into the general cavity of the body. They are also furnished with peculiar canals, serving for the conveyance of water to different parts of the body,—especially to the vesicles at the base of the ambulacra.

The sexes, contrary to the rule which we have seen to prevail in the lower *Radiata*, are always separate. The ova, when impregnated, become converted into ciliated embryos, which, breaking through the egg-shell, swim freely about in the water. The changes which these undergo in their progress towards maturity are exceedingly remarkable; and although our space forbids us from describing these with any minuteness, a short account of them is necessary to complete the natural history of the *Echinodermata*. The metamorphosis in question has been most fully observed in Star-fishes and Sea-urchins; and it is to these that we must direct our attention. The ciliated embryo, after its exclusion from the egg-shell, is of a globular form; this is converted into an irregular hexahedron, which gradually increases in height until it forms a four-sided pyramid. In the centre of the base of this pyramid is seen an opening,—the mouth,—which leads into a stomachal sac. It also contains four or more slender calcareous supports, running from one extremity to the other, and projecting at the base in the four-pointed spines. The little animal still moves by the action of cilia, which are particularly numerous along the course of the calcareous supports.

At a later period of its development the larva acquires a still more pyramidal form; and the processes of the calcareous supports are surrounded by lobes bearing the cilia. In this state it was long regarded as a distinct animal, and described under the name of *Pluteus*. But the most remarkable part of this metamorphosis consists in the fact that this larva does not become actually converted into the perfect Echinoderm, but that the latter sprouts, as it were, from this embryonic form, of which scarcely a trace remains in the mature animal. This is effected in the *Ophiuræ* by the following process:—Small sacs first make their appearance in the interior of the larva, surrounding the mouth; these gradually grow out of its substance, unite, and thus represent the disc of the Star-fish. After a short time the new animal forms a mouth for itself; having hitherto derived its nourishment through the mouth of the larva. The arms now begin to sprout; and soon afterwards the first commencement of the calcareous skeleton makes its appearance, in the form of little reticular grains, in the substance of the young animal. The further development goes on in the same manner, until at last the larva is cast off altogether, and the young *Ophiura* presents the form of its parent. It still, however, possesses cilia, by means of which it swims about for a time; but these afterwards disappear. The only part of the larva that remains in the perfect animal is the intestine, which, of course, is greatly modified. The point at which the connection was broken off between the larva and its developed bud is always marked by a plate of a peculiar character.

The *Echinodermata* are found in all seas, creeping slowly along the bottom by means of their curious little feet. In earlier periods of the world's history they appear to have been still more numerous and diversified in form than in the present day; one entire order, which played a most important part in the earlier stages of the formation of our planet, being now all but extinct.

Divisions.—The *Echinodermata* are divided into four orders. In two of these the body is more or less flattened or discoid in its form, and usually furnished with five or more arms. These in the first order, the *Crinoidea*, are slender, and formed of complete

calcareous rings or cylinders,—whilst in the second, the *Stellerida*, the calcareous covering of the arms is composed of separate plates. In the third order, the *Echinida*, the calcareous plates have become united into a regular shell; and the fourth includes the worm-like forms, the *Holothurida*.

ORDER I.—CRINOIDEA.

General Characters.—The *Crinoidea*, or *Sea-lilies*—so called from the resemblance which many of them present to flowers (Fig. 66)—were exceedingly abundant in former ages of the world; and their remains often form the great bulk of large masses of rock. During the whole or a part of their existence, these animals are attached to submarine bodies by a longer or shorter stalk, composed of calcareous rings similar to those of which the arms are composed. The body is of a cup shape, its lower convex surface—to the centre of which the stalk is attached—being composed of calcareous plates, whilst the upper disc is closed by coriaceous skin. In the centre of this is the opening of the mouth, and to one side the anus. The arms spring from the edges of the cup. They are either five or ten in number at their origins, although often branched higher up, formed of cylindrical or bead-like calcareous joints, furnished with slender jointed appendages, or *cirri*, one on each side of every joint; and, as the whole of these organs are exceedingly flexible, they are of the greatest importance to the animal in the capture of its prey.

Divisions.—An exception to this general structure is presented by the *Cystocrinida*—a fossil family which only occurs in some of the oldest formations. In these the body is round or oval, and entirely composed of numerous calcareous plates. They were attached by a short flexible stalk, the mouth was situated at the centre of the upper part, which projects a little from the general surface, with the anal opening a little to one side of it.

The family *Encrinida*, or the *Sea-lilies*, includes an immense number of fossil forms (Fig. 66); and one or two are still to be found in the West Indian seas. These animals were all supported upon a long stalk, at the extremity of which they floated in the waters of those ancient seas, spreading their long arms in every direction in search of the small animals which constituted their food. Each of these arms, again, was feathered with a double series of similarly jointed appendages; so that the number of separate calcareous pieces forming the *skeleton* of one of these animals was most enormous. It has been calculated that one species, the *Pentacrinus Briareus*, must have been composed of at least one hundred and fifty thousand joints; and “as each joint,” according to Dr. Carpenter, “was furnished with at least two bundles of muscular fibre—one for its contraction, the other for its extension—we have three hundred thousand such in the body of a single *Pentacrinus*—an amount of muscular apparatus far exceeding any that has been elsewhere observed in the Animal Creation.”

A *furrow* runs along the inside of the arms, covered with a continuation of the skin of the disc; and from this the ambulacra are protruded, as in other *Echinodermata*.

The third family, the *Comatulida*, or *Hair-stars*, includes a considerable number of animals, which bear a great resemblance, both in form and structure, to the *Encrinida*. They are, however, only furnished with a stalk during their young state, and on arriving



Fig. 66.—Encrinurus.

at maturity they quit their attachment, and crawl about freely at the bottom of the water, in the same manner as other Star-fishes. The body is flattened, and covered with separate calcareous plates; the lower, or ventral surface, bears the mouth and anus; and the ten slender arms are often branched to such an extent as to appear very numerous. They are furnished throughout their length with slender jointed cirri, similar to those of the *Encrinidae*, by the assistance of which, and the short ambulacra, the Hair-stars are enabled to grasp any object firmly, and creep about on submarine plants with great ease.

In their young state, the *Comatulæ* exactly resemble the animals of the preceding



Fig. 67.—*Comatula*.

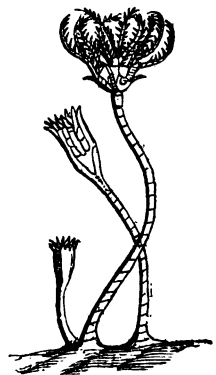


Fig. 68.—Young of *Comatula*:
(Described as *Pentacrinus Europæus*).

family, being supported upon a long flexible stalk, formed of calcareous cylinders. So close is this resemblance, that when first discovered the young of *Comatula* was described as a *Pentacrinus*. These animals are tolerably numerous in the seas of the present day, where they constitute, in fact, the principal representatives of their order. In the earliest ages of the world, their place was taken by the fixed *Encrinidae*; and the free *Comatulæ* do not make their appearance in any formation earlier than the Jurassic strata.

ORDER II.—STELLERIDA.

General Characters.—The second order, the *Stellerida*, is composed of animals with a flattened and more or less pentagonal body, usually bearing five arms of variable length, which, however, are not distinctly separated from the body, as in the *Crinoidæ*, and into which processes of the stomach are usually continued. The mouth opens in the centre of the lower surface of the disc; and the anus, when present, is always situated on the back. In the neighbourhood of the mouth of the animals of this and the following order, some curious prehensile organs are always to be found, which, from the peculiarity of their structure and actions, have been regarded as independent parasitic organisms, and described as such under the name of *Pedicellariæ*. They stand upon little tubercles, and consist of a long calcareous stalk, which bears at its extremity a singular forceps of three or four pieces. These are continually opening and closing, apparently for the capture of floating particles of food; and, singularly enough, they continue their movements even after the death of the animal. The skin is cori-

ceous, and the calcareous matter is deposited in it in separate plates, which allow considerable flexibility to the whole body; along the lower surface of each arm runs a very distinct furrow, from which the ambulacra are protruded.

The true Star-fishes do not occur in the earliest fossiliferous formations. They first make their appearance in the *Muschelkalk*, and continue increasing in numbers in the more recent strata. In our present seas they are exceedingly numerous, both in species and individuals; so much so, in fact, that some species, on the coast of Normandy, are commonly used as manure.

Divisions.—The *Stellerida* are usually divided into three families. The first, the *Euryalidae*,* or *Gorgon's Head*, present a considerable resemblance to the animals of the preceding order; the arms being distinctly separated from the body, and the internal organs entirely confined to the disc, which is of a roundish form. The anus is wanting; the arms have no furrow on their under surface, are always much branched, and usually furnished with cirri, producing the confused and tangled appearance which has caused them to be compared to the Gorgon's head, with its snaky locks. These animals are principally found in the tropical seas, although some species exist even in the icy waters of the Arctic regions. They are all rare.

In the second family, the *Ophiurida*, so called from the resemblance of their arms to serpents' tails (Gr. *Ophis* a snake, *oura* a tail), the body forms a roundish or somewhat pentagonal disc, furnished with five long simple arms, which, like the branched organs of the preceding family, have no furrow for the protrusion of the ambulacra. The *Ophiurida* are exceedingly plentiful in all our seas, and their remains occur in all the more recent marine strata of the earth's crust.

We come now to the family (the *Asterida*) of which the common Star-fish (Fig. 1), so abundant on our coasts, is an example. In this family the arms appear to be merely prolongations of the disc; they are usually five in number, and the plates from which the ambulacra are exerted are placed in deep furrows, which run along the lower surface of the arms. In some species the arms are very short; and in others the animal forms a flat pentagonal disc, with five ambulacral furrows excavated in its lower surface. In the centre of this the mouth is situated, and the ramifications of the stomach extend to a greater or less distance into the arms. Most of the species of this family possess an anal aperture; but this is wanting in some.

ORDER III.—ECHINURA.

General Characters.—In this order the development of calcareous matter in the skin attains its maximum. The plates, instead of being distinct, as in the Star-fishes, are firmly attached to each other, forming a convex shell, more or less complete, which prevents all flexion of the body of the animal. This shell presents two openings, a mouth and an anus; the latter is generally situated at the top of the shell, opposite to the mouth, and is surrounded by moveable plates. The division of the animal into five parts is as distinct here as in the Star-fishes, notwithstanding the total absence of arms; the holes through which the little sucking feet are protruded being arranged upon five rows of plates, which usually run from the centre of the top of the shell to the angles of the oral opening; or, when they are confined, as is sometimes the case, to the dorsal surface, they form a distinct five-rayed star surrounding the apex of the shell. The mode in which the capacity of the shell is increased, is exceedingly curious and interesting. It is entirely covered by a skin of greater or less thickness; and, it appears, that,

* From *Euryale*, one of the Gorgons.

in spite of the close proximity of the edges of the plates, there is yet room for the passage of a minute layer of skin through all their interstices. It is in this that the deposition of calcareous matter takes place, so that, instead of adding fresh matter to the shell only at the oral aperture, as in the *Mollusca*, the animal increases the size of its domicile in proportion to its growth, by continual additions to the edge of every plate of which it is composed. New plates are also often added in the neighbourhood of the superior orifice. Next to this peculiarity in the form of the shell, the most striking character of the *Echinida* consists in the numerous spines, frequently of large size, with which the shell is covered. These are articulated to the numerous tubercles presented by the surface of the shell; the base of the spines being hollowed for the reception of the convex surface of the tubercle. In consequence of this mode of attachment, the spines possess a considerable power of movement; and, for this purpose, they are furnished with bands of a muscular nature,—and in some species they are even attached to the tubercles by a round ligament inserted into the base of the spine and the apex of the tubercle, and resembling in many respects the ligament of the hip-joint in man. These spines appear to be used as locomotive organs; they also serve to bury their owner in the sand when circumstances require this concealment; and some species appear, by the same means, to excavate hollows even in hard rocks.

Divisions.—The *Echinida* are divided into four very distinct families. In the first, the Sea-eggs (*Cidaridæ*), the body is nearly globular (Fig. 69), with the mouth in the middle of the under surface, surrounded by a naked or warty skin. The anus lies in the middle of the dorsal surface opposite the mouth, surrounded by a rosette of

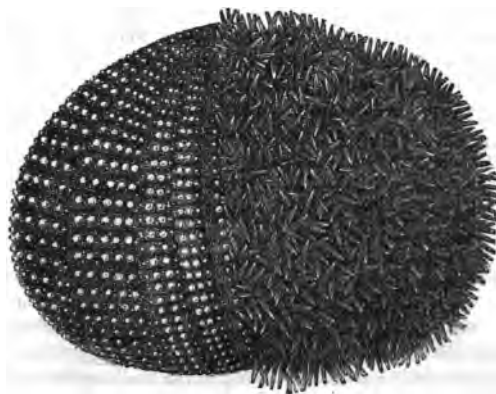


Fig. 69.—Shell of *Echinus*, or Sea-urchin; on the right side, covered with spines; on the left the spines removed.

curious plates, which form the orifices of the generative apparatus. It is in this family that the masticatory apparatus attains its highest development, presenting the complicated form represented in Fig. 65. The ambulacral spaces run from the mouth to the anus; and the intervening plates are covered with tubercles and spines, the latter of which are sometimes several inches in length, and as thick as a man's finger. These animals inhabit the seas of all parts of the world; and some species are used as food, even on the European coasts of the Mediterranean.

The animals of the second family, the *Clypeastridæ*, have the body of a somewhat discoid form; the shell is very thick, and covered with small tubercles, from which short, thin, hair-like spines take their rise. The mouth is situated in the middle of the lower surface, and is armed with a masticatory apparatus less complicated in its structure than that of the preceding family; but the anus, instead of being placed on the back of the shell, opens on its lower surface a little behind the mouth. The apex of

the shell is occupied by the genital plates; and the rows of ambulacra form a five-rayed star surrounding these on the dorsal surface of the shell.

The *Cassidulidae*, forming the third family, are of a roundish or oval form, generally convex, and covered with very fine spines.

The mouth is placed in the middle of the lower surface, with the anus behind it, sometimes on the margin. But these animals are especially distinguished from the two preceding families by the total absence of any masticatory apparatus in the mouth. This is equally deficient in the fourth family, the *Spatangidae*,—sluggish animals, which are usually found imbedded in sand, and with their intestines full of the same savoury and nourishing substance: taken in, no doubt, for the sake of the minute particles of organic matter which it might have contained. They are usually of a heart-like form, with the mouth at the anterior margin of the lower surface, and the anal orifice on its posterior margin. The ambulacra are generally confined to the dorsal surface, where they form four or five rays, and the surface of the shell is covered with fine hair-like spines, amongst which a few of larger size may be distinguished.

ORDER IV.—HOLOTHURIDA.

General Characters.—In the fourth and last order the body acquires a worm-like form, thus apparently leading us towards the lower groups of the next division. The radiate structure is in fact scarcely recognisable in these animals, except in the arrangement of the tentacula which surround the mouth. The body is always more or less elongated, with the mouth at one end and the anal opening at the other; the calcareous deposit in the skin is reduced to scattered granules; and in one family the ambulacra are entirely wanting.

Divisions.—This order is divided into two families. The first, the *Synaptidae*, are characterized by the total absence of ambulacra, the motions of the animals being assisted by peculiar anchor-like processes of the calcareous grains, which project from the skin, and roughen the surface of the animal.

In the *Holothuridae* (Fig. 70), on the contrary, the ambulacra, although short, exactly resemble those of the other *Echinodermata* in their structure and action. The mouth is surrounded

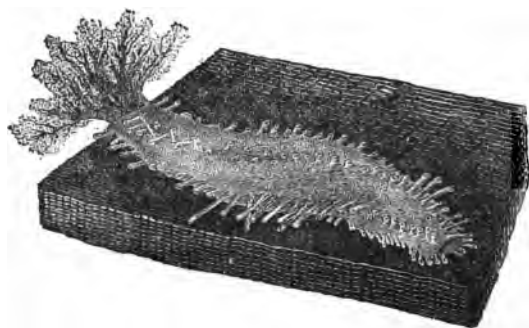


Fig. 70.—Holothuria.

by a ring of calcareous plates, serving for the attachment of the longitudinal muscles, by which the contractions of the body are effected. These animals inhabit the seas of most parts of the world. Some of them are eaten even by European populations; and the Trepan (*Holothuria edulis*) is an article of luxury amongst the Chinese.

This animal, which is very abundant on the north coast of New Holland, is collected

there by the Malays in large quantities, dried and packed up in bags for the Chinese market. The Malays and Chinese meet at the Island of Macassar, where the principal trade in this delicacy is carried on; and the quantity annually brought to that place by the fishermen is said to amount to upwards of four hundred tons. The price varies according to quality, from eight dollars to one hundred and fifteen dollars per pecul (133lbs.)

The *Echinodermata* conclude the series of animals generally termed *Radiata* by zoologists; but it is probable that further researches will show the necessity for great modifications in this part of zoological classification. There appears to be little to connect the hard-skinned Echinoderms with the delicate gelatinous animals composing the other four classes; and Mr. Huxley has already proposed to form these into a separate group, denominated, from the constant presence of thread cells, *Nematozoa*. The *Echinodermata* would then be regarded as aberrant forms of the articulate division; a view to which the study of their metamorphosis lends considerable support.

DIVISION III.—ARTICULATA.

Great as is the diversity of form and structure presented by the *Radiata*, the animals forming the present division perhaps exceed them in this respect. So great is this diversity, in fact, that it is almost impossible to give any common characters which shall positively include the whole; and some of the most eminent modern zoologists have proposed the establishment of a separate division to include the lower forms. By this means, however, the difficulty is lessened rather than got rid of altogether; for, although a tolerably coherent group is thus obtained for the higher forms, the lower ones still vary to such an extent, that a very loose character is necessary to enable them to be united in a single group. We shall, however, adopt these *sub-divisions*, as they may tend to render this part of our subject more intelligible. The general characters of the division have already been given at sufficient length (p. 198).

SUBDIVISION I.—VERMES.

General Characters.—The animals of the first sub-division, the *Vermes* or *Helminths*, are usually of a very elongated form; and in the higher groups the division of the body into a number of segments is very distinct; whilst in some of the lower forms this general characteristic of the articulate series is quite unrecognizable. The segments, when present, are generally mere repetitions one of another; and the appendages with which they are frequently furnished follow the same rule.

The nervous system, which, in the *parasitic* groups (*Entozoa*), is, as might be expected, in a very rudimentary condition, gradually increases in complexity; until in the *Annelida* or *tree worms*, it consists, as in the most highly endowed *Articulata*, of a ventral series of ganglia, united by nervous cords, and communicating with a nervous mass of considerable size (brain) situated in the head. In proportion to this gradual elevation of the nervous system is the development of the different organs of the body. This is especially remarkable in the case of the lateral appendages, which are entirely wanting in the lower groups; but in the *Annelida* they make their appearance often in a very complicated form, such as branchial and natatory plates, and jointed bristles serving as feet. In none, however, do they present the peculiar structure of the limbs possessed by the other *Articulata*, the construction of which will be described in the proper place.

Divisions.—The *Vermes* may be divided into four classes, which are generally distinguishable by their external appearance. Of these, the first two are for the most part parasitic, living in the interior of other animals, few of which, in fact, are exempt from the visits of these unwelcome guests. Of these, the first, the *Flat-worms* (*Platyelmia*) have the body flattened, and generally more or less ovate and leaf-like; these present the greatest divergence from the articulate type. In the second, the *Nematalmia*, or *Round-worms*, the body is usually elongated and cylindrical, and the division into segments is often indicated by annulations of the skin. The other two classes are composed principally of aquatic animals. A few are terrestrial in their habits, but none are parasitic. One of these, the *Rotifera*, or *Wheel Animalcules*, includes a number of minute creatures furnished with a pair of ciliated organs at their anterior extremity; whilst the *Annelida*, or *true worms*, have the body distinctly divided into segments, generally furnished with lateral appendages, and with a well developed nervous system. The blood, in this last class, is also generally of a red colour.

CLASS I.—PLATYELMIA.

General Characters.—The study of the *Entozoa*, or internal parasites, from the nature of their habitations, is perhaps not one of the most attractive branches of Zoology; yet few animals can present a better claim to our notice, from the circumstance that many of them find their natural residence in our own bodies, and in those of our domestic animals, where they often do us a great amount of injury. They have a still stronger claim to the attention of the scientific zoologist, from the number of points connected with their natural history, which still remain to be cleared up, and from the wonderful nature of those portions of the history of their development, which have been revealed by the recent researches of some of our most eminent naturalists.

By far the greater number of the *Platyelmia* pass the whole or the greater portion of their existence inclosed within the bodies of other animals, of which few are without species of these parasites peculiar to themselves. Some species, however, live in the water, where they swim about freely by means of cilia. They all, however, have the body much flattened, and usually of a more or less ovate form, without any traces of segmentation; the only exception to this rule being presented by the *Tape-worms*, in which, as is well known, the body is of great length, and composed of a multitude of similar joints. We shall see, however, on studying the development of these animals, that the exception is more apparent than real; for it appears that the Tape-worm may be regarded as a compound animal, each joint being capable of a certain amount of independent existence.

The nervous system consists of a pair of ganglia situated in the anterior extremity of the body, and giving off two slender filaments, which run down each side of the body. No special organs of sense have been found in the parasitic species; but those which live free in the water have several dark spots, each containing a distinct lens, placed close to the central ganglia, and these are considered to be true eyes. With the exception of the cilia of the aquatic forms, no organs of motion are to be met with in the *Platyelmia*. The parasitic species are generally furnished with hooks or suckers for maintaining themselves in their position; but their movements are almost entirely confined to a muscular contraction and dilatation of the body.

Divisions.—The *Flat-worms* are divided into three orders, of which two are composed of parasitic, and one of free-swimming animals. They may be regarded as forming two groups or sub-classes, of which the second is distinguished by the pos-

session of cilia; the others being destitute of these organs. The two parasitic orders are the *Cestoidea*, or *Tape-worms*, with long, usually jointed bodies; and the *Trematoda*, with short, elliptical, or discoid forms.

ORDER I.—CESTOIDEA.

General Characters.—The general appearance of the animals belonging to the order *Cestoidea* is well shown in the annexed figure, which represents the common Tape-worm of the human intestines. The body is composed of numerous joints or segments, each exactly resembling each other; these are often several hundreds in number, and the animal sometimes attains a length of upwards of ten feet. The skin is exceedingly soft and tender, and the muscular system possesses very little energy; so that the

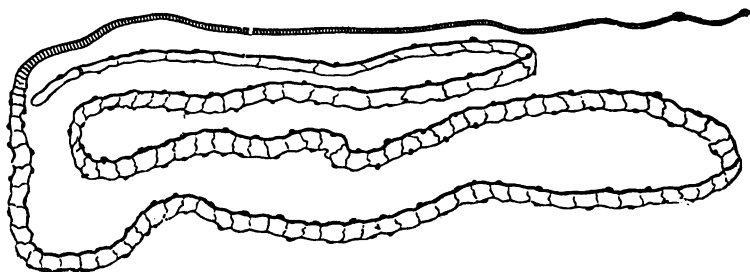


Fig. 71.—*Tænia Solium*. The common Tape-worm.

movements of the animal are confined within very narrow limits. Its anterior extremity is formed by a small head, furnished with hooks and suckers, by means of which the animal anchors itself to the intestines of its victim; it also contains the rudiments of the nervous centre, the filaments given off by which only run through a few of the first segments. The animal appears to possess no mouth or digestive organs; so that it must derive its nourishment entirely by absorption through the skin. On each side of the body runs a long vessel, passing through all the segments; these are united at each articulation of the body by a transverse vessel. Each segment contains both male and female sexual organs; and when these have arrived at maturity, the segment is cast off to seek a new place in which its ova may be developed. For this purpose the joints, when cast off, are endowed with a considerable power of motion, and will live for several days when placed in favourable circumstances. In some cases they have been observed to develop peculiar organs, which they do not possess in their compound condition. The orifices of the sexual organs are placed at one side of each segment, and these apertures are placed alternately on both sides of the body of the animal.

The development of these animals presents some of the most remarkable phenomena that have yet been discovered in the natural history of animals. Some curious parasitic worms are found, not in the intestines, but in the solid tissues of many herbivorous animals, which, from the structure of the head, have always been ranged in the neighbourhood of the Tape-worms, although their bodies, instead of being drawn out to an enormous length and divided into numerous segments, are composed almost entirely of a simple bag of fluid.

Some of these parasites are simple,—that is to say, the sac bears only a single head;

in other cases they develop a multitude of these organs, sometimes from the internal, sometimes from the external surface of their walls. These worms were long regarded as forming a distinct order of parasitic animals; but recent experiments have shown, that when they are administered to particular carnivorous animals with their food, the vesicle of fluid is cast off, the head attaches itself, and gradually develops the long jointed body of a true *Tenia*. The observations were first made upon the Cystic worms which inhabit the liver of the mouse and rat; these, when given to cats, were found to produce in their intestines *Tænia*s of the species usually infesting those animals. Experiments have since been instituted upon Cystic worms from different species of herbivorous animals, and these all produce Tape-worms of different kinds when introduced into the bodies of carnivorous animals. The administration of mature segments of Tape-worms to the herbivorous species, has also been found invariably to produce a development in the tissues of their organs of the corresponding Cystic worms; so that we may consider it a well-established fact, that the ova of the Cestoid worms are not, as a general rule, developed in the same species of animal which is infested by the mature *Tænia*.

But, it may be asked, how does the embryc *Tænia* find its way from the stomach of its host, through the various tissues of its body, until it reaches the particular organ in which its development is to be carried on? This subject is still enveloped in a certain amount of obscurity; but some recent researches of Professor Van Beneden appear to throw a little light upon it. That zoologist observed that the embryos of a *Tænia* found in the intestines of the common frog, were furnished with six spinous organs, of which two were straight, and the other four slightly hooked at the extremity. By an action of the four-hooked spines, very similar to that of the arms of a man when swimming, the little creatures were enabled to push themselves through the broken tissues of their parent; the two straight spines assisting to pierce a passage, and, no doubt, maintaining them in their position whilst the hooks were brought up for a fresh stroke. In this manner, as Professor Van Beneden observes, they would have no difficulty in penetrating any tissues, or in reaching any part of the body of the animals appointed for their further development.

Professor Van Beneden appears to consider that the history of the Cestoid worms affords another instance of an "alternation of generations" analogous to that of the *Medusa*, referred to at page 252. In this view the Cystic worm (*Scolex* V. B.) corresponds with the simple Hydraform polype; the compound animal known as the Tape-worm (*Strobile* V. B.), with the elongated polype in process of division; and the mature, separate segment (*proglottis*), with the perfect sexual *Medusa*.

An exception to this general rule appears, however, to be presented by the tape-worm of the human subject; at least, it is not easy to understand how the Cystic worms could withstand the heat usually employed in cooking our animal food. Recent experiments have shown that the administration of adult proglottides of *Tænia solium* to pigs, produces a great development of the *Cysticercus cellulosa* (Fig. 72); but in what manner this parasite can be introduced into the human organism is still unknown. The *Cysticercus cellulosa* is also found in the tissues of the human body.



Fig. 72.—*Cysticercus Cellulosa*.
a, head enlarged.

Two species of Cestoid worms inhabit the human intestines—the *Tænia solium* and the *Bothriocephalus latus*. The former is the ordinary *Tape-worm*, the second occurs only in particular countries,—in Holland, Poland, and Switzerland. In the Cystic form some of these worms do great injury to domestic animals; one of the most noxious is the so-called *Cœnurus cerebralis*, inhabiting the brains of sheep. Many other interesting facts are connected with the history of these animals; but our space forbids us from entering into further details.

ORDER II.—TREMATODA.

General Characters.—These animals, which are all parasitic, present some resemblance to the individual segments of which the Cestoid worms are composed. They are usually of an elliptical or oval form, and very flat; the skin is soft, but usually contains a number of calcareous granules. The whole body is very contractile. At one or both of its extremities it is furnished with suckers to enable it to adhere firmly to its host, and at its anterior extremity with a mouth. At a little distance from the mouth the narrow intestinal canal usually divides into two, which mostly terminate in blind extremities; in some cases, however, the two intestines meet towards the hinder part, so as to form a complete circle. All these animals are hermaphrodites, and the history of their development presents many points of almost equal interest with those exhibited by the Cestoid worms.

Divisions.—They form three families. In the first, the *Distomida*, the animals possess two suckers, of which the anterior contains the mouth. Of these the Fluke (*Distoma hepaticum*), which infests the livers of sheep, is a well-known example. Other species live in the intestines, the brain, and even the eyes, of other animals.

The animals of the second family, the *Tristomida*, are furnished with three suckers; two small ones at the anterior extremity, between which the mouth is situated, and a larger one at the hinder extremity. These worms principally infest the gills of fishes, as do also those of the third family, the *Polystomida*, characterized by the presence of several suckers at the hinder extremity of the body, whilst the anterior extremity is either entirely destitute of those organs, or only possesses a small one, in which the mouth is situated. This family includes the singular *Diplozoon paradoxum*—an animal which appears to be compounded, like the Siamese twins, of two perfect individuals, each containing precisely the same organs.

ORDER III.—PLANARIDA.

This order includes most of the free *Platyelmia*. These animals are of an oval or elliptical form, and very commonly furnished with an extensible proboscis, springing from the ventral surface, and leading into a large digestive cavity, which gives off numerous ramifications into the substance of the body, but possesses no anal opening. These animals are of a gelatinous consistency, and enjoy such a power of self-contraction that they can reduce their whole substance to the form of a lump of jelly, in which condition they occasionally force themselves rather disagreeably upon the notice of incautious water-cress eaters. They inhabit both salt and fresh water, where they swim about rapidly by an undulating movement of the body, in the manner of a leech, and creep with great ease upon stones and aquatic plants. They are generally of small size, but exceedingly voracious. Like the polypes, which they resemble in their gelatinous nature, they appear to be capable of almost endless increase, by the way

which might be expected to lead to their destruction. Sir John Dalyell, in his observations on these animals, speaking of the black *Planaria* (*Planaria nigra*), says that "it is privileged to multiply its species in proportion to the violence offered to its otherwise delicate frame. It may almost be called immortal under the edge of the knife. Innumerable sections of the body all become complete and perfect animals. If the head be cut off, a new head replaces it; if the tail be severed, a new tail is acquired." Still more remarkable was an instance of spontaneous separation of the head of one of these animals, which took place under the eyes of the same observer.

In South America, Dr. Darwin observed some terrestrial animals which approached the *Planaria* very closely in their characters; they lived amongst rotten wood, upon which they appeared to feed, and were marked on the back with stripes of bright colours.

The family of *Nemertida*, or *Ribbon-worms*, must be referred to in this place, as it probably forms the type of a fourth order of *Platyelmia*. It is composed of animals with elongated ribbon-like bodies, possessing a protrusible proboscis, a distinct nervous system, and a digestive canal with a distinct anus. As far as we know at present, the sexes are on distinct individuals. Amongst these one species, the *Borlasia*, inhabiting the coasts of France and England, attains a length of upwards of fifty feet. This tremendous worm remains coiled up during the day under stones, going about at night in search of prey.

The *Turbellarida* also—a family of minute worms inhabiting both salt and fresh water—appear to belong to this order. Like the preceding animals, they possess an intestinal canal with two openings, and the sexes appear to be separate. The classification of these creatures is still, however, involved in great obscurity; and much still remains to be done before it can be brought to a satisfactory condition.

CLASS II.—NEMATHELMIA.

General Characters.—The animals belonging to this class are of a more or less elongated, cylindrical form, with the skin much thicker and stronger than that of the preceding parasitic worms, and generally wrinkled in such a manner as to give the body an annulated appearance. The nervous system, in the higher forms, consists of a pair of ganglia, situated in the anterior extremity, and united by a slender nervous ring, which surrounds the oesophagus; from these, two filaments take their rise, and run through the whole length of the body. In the lower orders no undoubted nervous system has yet been recognised. As far as our present knowledge goes, the *Round-worms* are unisexual; the males, which occur far more rarely than the females, are always smaller than the latter, and usually present distinct copulative organs. No such extraordinary metamorphosis as that which we have seen to prevail amongst the flat worms occurs in the development of these creatures, which, however, are as yet but imperfectly known. They not only inhabit the intestines of other animals, but many species are also to be met with in the interior of completely closed organs, to which they must have obtained access in their earliest stages.

Divisions.—The *Nematelmia* form three very distinct orders,—the *Acanthocephala*, which possess a proboscis armed with a formidable apparatus of hooks, but are apparently destitute of an alimentary canal; the *Gordiacae*, long thread-like worms, with an intestinal canal, but without an anus; and the *Nematoidae*, in which a perfect intestinal canal exists.

ORDER I.—ACANTHOCEPHALA.

This order, which includes only a single genus, is composed of parasitic worms often of considerable size, which find their habitation in the intestines of various animals, especially fishes. One species in particular, the largest in the order, is common in the intestines of swine, where it sometimes attains a length of eighteen inches. The body is thick, and divided into rings by a series of transverse wrinkles; the head is armed with rows of reversed spines, which not only serve to fix the animal in its abode, but also enable it to bore through the intestines of its unfortunate victim, who sometimes falls a sacrifice to this propensity of his uninvited guest. These creatures appear to possess no alimentary canal; their nourishment is entirely obtained by absorption through the skin, beneath which is a curious areolar structure, which is probably subservient to this purpose.

ORDER II.—GORDIACEA.

The *Gordiacea*, or *Hair worms*, are at once distinguishable by the extraordinary length of their bodies (Fig. 73), which frequently present a close resemblance to a horse-hair; so close, indeed, that in former times the popular belief ascribed their origin to the introduction of horse-hairs into the water in which they are found.



Fig. 73.—*Gordius Aquaticus*.
a, tail.

These animals live as parasites in the bodies of various species of insects, to which their size is often so disproportionate, that when the worm is coiled up

within the cavity of an insect's body, scarcely any space is left for the internal organs of its unfortunate host. Dr. Baird has recently described a species of *Gordius* from the common violet Ground Beetle (*Carabus violaceus*), an insect scarcely an inch in length, the worm being upwards of eleven inches; whilst other species, of which the victims are unknown, attain a length of about three feet. When mature they quit the bodies of the insects, at whose expense they have been nourished, and seek some piece of water or moist situation, where they deposit their ova in long chains. At this period they sometimes suddenly make their appearance in vast numbers in particular spots, giving rise to reports of worm rains. It seems probable that the evolution of the young proceeds to a certain distance in the situations where the eggs are deposited; but when, or in what manner, they afterwards obtain access to their destined victims, is still unknown. One of the most singular circumstances connected with their history is, that if, by any chance, on breaking out of their insect-home they find that dry weather has produced a state of things incompatible with their notions of comfort, they quietly allow themselves to be dried up, when they become perfectly hard and brittle; but, strange to say, the moment a shower of rain comes to refresh the earth with its moisture, the dormant *Gordii* immediately recover their activity, and start off in search of a suitable place in which the great object of their visit to solid earth may be effected.

ORDER III.—NEMATODEA.

With the exception of one family, all the worms included in the order *Nematodea* are parasitic in the bodies, and principally in the intestines of other animals; they are, in fact, amongst the most common and the most injurious of *Entozoa*. In the form of

their bodies they frequently resemble the common Garden-worm, although some are much more elongated, and often taper to a very fine point at one end; the skin is more or less wrinkled, giving them an annulated appearance. These are unmistakably the highest forms of intestinal worms; they present a distinct nervous system, an alimentary canal, furnished with a mouth and an anal opening, and distinct sexual organs. The history of the development of these animals is but imperfectly known. It appears probable that in many cases a different situation is required for the evolution of the young, to that inhabited by the mature animals; for at certain periods the latter, apparently impelled by some wandering instinct, quit the intestines, either by allowing themselves to be carried out along with discharged matters, or by actually boring through the walls of their habitation into the tissues beyond them. The object in the latter cases appears to be the deposition of their eggs in the blood-vessels of their host; at least, a species found in the frog deposits its ova in this situation. The young animals appear to be carried by the circulation to some position suitable for their development, when they inclose themselves in a minute capsule or cyst amongst the tissues of the body, and remain at rest for some time. On breaking out of this capsule they find their way to the intestines, where they remain until their instincts prompt them to imitate the example of their parents.

This order includes the common *Ascaris*, or *Round-worm* of the human subject, as well as the little *Thread-worms* (*Oxyuris*) which are often so troublesome to children. These are rarely injurious, unless present in great numbers. Far different is the case, however, with the *Strongylus gigas*, a worm sometimes attaining a length of two or three feet, and the thickness of a man's little finger, which usually inhabits the kidneys of swine, but sometimes finds its way into the same organ in man. This tremendous worm, by destroying the organ in which it has taken up its abode, is said not unfrequently to cause the death of its host.

This order also includes the dreaded Guinea-worm (*Filaria medinensis*), which appears to occur in most parts of tropical Africa. This worm lives in the cellular tissue beneath the skin, and between the muscles of man, confining its attacks principally, though not exclusively, to the lower extremities, where it often produces considerable pain. It is said occasionally to attain a length of twenty or thirty feet; but its average length is five or six. It is extracted by winding it very slowly upon some object, an operation in which great care is said to be necessary, as if the worm be broken its fluids produce a very painful effect. When arrived at maturity, the *Filaria* comes to the surface, where it breaks to pieces and sets free the innumerable young with which it is crammed.

In this order we also place the *Anguillulide*, the so-called *Eels* of paste and vinegar. These are minute, thread-like worms, exhibiting distinct digestive and generative organs, which occur often in great numbers in putrefying substances.

CLASS III.—ANNELEIDA.

General Characters.—The *Annelida*, in general, present a more complicated organization than any of the preceding animals; the division of the body into segments is usually distinctly recognizable, and the segments are almost universally furnished with external appendages, which are sometimes jointed. The majority live in water, or in damp situations; a very few only are parasitic in their habits.

The head in most of these animals is distinctly marked, and furnished with organs of sense, such as eyes, tentacles, and in some instances auditory vesicles, containing

otolithes. The nervous system, in the higher forms, exhibits the articulate type of structure very distinctly; it usually consists of a series of ganglia running along the ventral portion of the animal, and united by a pair of slender filaments, by which they also communicate with the central mass, or brain, which is inclosed in the head; this is composed of two ganglia, united by a ring surrounding the oesophagus. In the lower forms the nervous system approaches that of the preceding classes.

The lateral appendages, which serve principally as organs of motion, are very

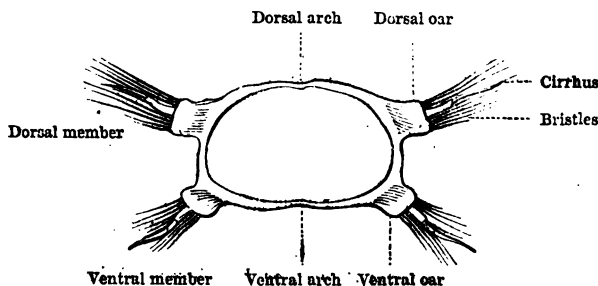


Fig. 74.—Transverse section of an Annelide (*Amphinome*).

variable in their structure and arrangement, sometimes occurring on all the segments of the body, sometimes only on the anterior or on the middle segments; sometimes four and sometimes two in number on each segment. They usually consist of lobes of skin, furnished with bundles of bristles of very various forms, and with jointed cirri or tentacles (Fig. 74); they also commonly bear the respiratory organs, or branchiae (Fig. 75). In some *Annelida*, as the Leeches, no trace of external organs is to be seen; whilst in others, as the Earth-worms, they are reduced to a few bristles, which assist the animal in its progress through the earth. It is to be observed, however, that even in the highest *Annelida* the jointed cirri are always easily distinguishable from the limbs of the second section of the *Articulata*.

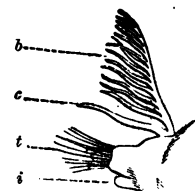


Fig. 75.—Foot and branchia of *Eunice*.

b, branchia; c, cirrus; t, bristle tuft; i, ventral cirrus.

The digestive apparatus consists of a straight intestine, running through the body from one extremity to the other. The mouth is usually armed with jaws, and the opposite extremity of the intestinal canal always terminates in an anal opening. The vascular system is also very distinctly developed, and the nutritive fluid is usually of a red colour, sometimes green or yellow.

The sexes are usually distinct, although a few—as the Leeches and Earth-worms—are hermaphrodites; but even in these self-impregnation does not take place. Some *Annelida* appear to propagate also by spontaneous division; and many of them can reproduce parts lost by accidental injury.

Divisions.—The *Annelida* may be divided into two groups, characterized by the presence or absence of external respiratory organs. The abranchiate Annelides include two orders,—the *Suctorioria*, or Leeches, characterized by the possession of a sucking disc at the posterior, and usually also at the anterior extremity; and the *Scolecina*, or Earth-

worms, in which these suckers are wanting, but which are furnished with a double row of bristles along the under surface of the body. The branchiferous group is also divided into two orders,—the *Tubicola*, the animals composing which form a tube for their habitation, and the *Errantia*, which enjoy no such protection.

ORDER I.—SUCTORIA.

General Characters.—The animals belonging to this order, of which the common medicinal Leech (Fig. 76) is a familiar example, are characterized by the total deficiency of any lateral appendages; their motions being effected by undulations of the body whilst

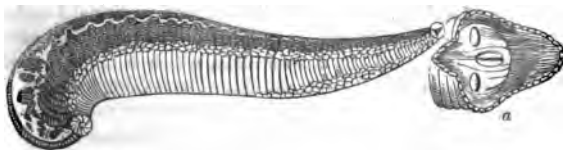


Fig. 76.—The Common Leech (*Sanguisuga officinalis*).

swimming, or by the alternate attachment of the sucking discs with which the two extremities of their bodies are usually furnished. They all appear to live by

sucking the blood of other animals; and, for this purpose, the mouth of the Leech is furnished with an apparatus of horny teeth, by which they bite through the skin. In the common Leech three of these teeth exist, arranged in a triangular, or rather tri-



Fig. 77 — Tooth of the Leech.

radiate form, a structure which accounts for the peculiar appearance of leech bites in the human skin (Fig. 76, a). Each of these teeth has a minutely serrated edge (Fig. 77), which, when worked backwards and forwards in contact with the skin, soon saws it through, when the teeth are retracted, and the blood is then pumped from the wound by the alternate dilatation and contraction of the muscular oesophagus. In the *Cleptinidae* this structure disappears, giving way to a protrusible proboscis. The intestine is of very large size, and usually extends on each side into short blind sacs or processes, the

distension of which, during the act of suction, must necessarily increase its capacity. Respiration appears to be performed by a system of aquiferous canals, lined with cilia, which open externally, by a series of minute orifices, on each side of the body. The vascular system is well developed. Nearly all these animals are hermaphrodite. The deposition of the eggs is attended with some very singular circumstances. At the period of oviposition, a peculiar gelatinous band is produced round the anterior part of the body near the orifice of the generative organs, which is situated in this part. The Leech lays its eggs in this gelatinous matter; and when all are deposited it withdraws its body from the band, which then closes up, and forms a complete capsule, within which the eggs are inclosed. It appears, from a statement of M. Frémond, that (in addition to these capsules, or cocoons, as they are called, containing a number of ova) the Leech also sometimes produces a "compound egg, formed of a transparent membrane, full of a liquid, in which little globules soon begin to appear; these globules are, in fact, so many germs of Leeches, and during development take the form of little worms, which soon leave the egg by an opercular hole at its extremity."

The nervous system in the *Suctoria* is usually well developed; and the anterior sucking disc bears a row of eight or ten eyes, which, however, appear to be of very imperfect construction.

Divisions.—This order is divided into three families. The first, the *Malacodermida*, presents many points of resemblance to the Trematode worms; the mouth is unarmed, the substance of the body semi-transparent, the nervous system composed of a single ganglion and filament on each side of the body; and there is a single sucking disc at the posterior extremity. These worms live parasitically within the mantle of various marine bivalve Mollusca.

In the *Clepsinida*, the body is of a leech-like form, but very much narrowed in front, and the mouth is furnished with a protrusible proboscis. These animals live in fresh water, where they may often be seen creeping upon aquatic plants. They prey upon the water snails (*Lymnaea*).

To the third family, the true Leeches (*Hirudinida*), the common medicinal Leeches belong. Two species of Leech are commonly used in medicine,—the *Sanguisuga officinalis*, a native of the South of Europe, and the *S. medicinalis*, which is found principally in the northern countries of the same continent, and occurs, but rarely, in England. Most of the Leeches used in England are imported from Hamburg; but the pools and marshes in which the animals are collected are situated at a great distance from that emporium of the trade, in the thinly populated countries of eastern Europe,—Hungary, Bohemia, and Russia.

The supply in these countries, however, appears to be nearly exhausted, and much of our supplies are now derived from regions still further to the east. The animals are caught by means of baits put into the water, or by the fishermen wading into the pools with naked legs. The importance of the Leech in medicine is well known; but few, perhaps, are aware of the enormous consumption of these Annelides that really takes place. Some idea of this may be formed, however, from the fact mentioned by Dr. Pereira, that some years ago “four principal dealers in London imported, on the average, 600,000 monthly, or 7,200,000 annually!” The annual consumption in Paris has been estimated at 3,000,000, and that of the whole of France at no less than 100,000,000. No other creature, so low in the scale of organization, gives rise to so extensive a commerce as this. The Leeches are sometimes imported in bags, but more frequently in small tubs, closed with stout canvas, to allow the passage of air. Each of these tubs contains about 2,000 Leeches.

But if the medicinal Leech puts forward a strong claim to our attention, on the ground of the services which it renders to mankind, there are others which force themselves upon our notice from the very opposite consideration. These are principally confined to hot countries, where, however, they are often great pests. In Egypt, during the invasion of that country by Napoleon, the French soldiers were often exposed to great torment from the numbers of Leeches infesting the pools. When the men, fatigued with their march under the burning sun, rushed eagerly to drink, these bloodthirsty animals would fix themselves to the interior of the mouth or nostrils, producing intolerable annoyance to men already half-maddened by vexation and fatigue.

A still more remarkable instance is afforded by the small Leeches which infest Ceylon. These animals are about an inch and a half in length. They live principally in the forests, amongst the dead leaves, in damp places; but often make their appearance in other parts of the island during wet weather. Wherever they occur, however, they seem always to be on the look-out for blood; and some instinct tells them that, even under the clothes of Europeans, this wished-for delicacy is to be obtained. The incautious invader of their domain soon feels a peculiar sensation of moisture about his legs; and, on examining into the cause, he finds, to his dismay, that they are bathed in blood; or

should he, by chance, wear white trousers, he may perhaps receive the first horrifying intelligence of what is going on, by the sudden appearance of red stripes upon his nether habiliment. If the traveller, made wise by experience, should resort to the expedient of tying his trousers round his boots, or (which is said to be the best course) his boots over his trousers, the little blood-suckers will mount still higher in search of their manorial rights; and an unpleasant dabbled sensation about the neck soon shows that the enemy has succeeded in scaling the citadel. The legs of horses, passing through the districts infested by these pests, are frequently completely covered with blood in consequence of their attacks.

Some species of this family, forming the genus *Piscicola*, live as parasites upon various fresh-water fishes; whilst those of the genus *Branchiobdella*, which are quite destitute of eyes, inhabit the branchiæ of some *Crustacea*.

This appears to be the proper place to allude to some singular marine animals which have been placed, by some zoologists, amongst the *Echinodermata*, by others amongst the *Annelida*. These are the species of the genus *Sipunculus* and its allies, which constitute an order of animals for which the name of *Gephyrea* has been proposed, in allusion to the apparent connection which they establish between the *Echinodermata* and the articulate series. Their bodies are cylindrical, and rather thick, covered with a tough skin, in which a few bristles are sometimes inserted, but which neither contains calcareous particles nor the tubular sucking feet of the true Echinoderms. Their habits are very similar to those of the common lob-worms, and like these they are much sought after as baits by the fisherman. They live in the sand, where they move about, much in the same way that the common garden worm does in moist soil; they are destitute of eyes and other organs of sense, and the mouth is armed with a curious proboscis. Some species, as the *Sipunculus Bernhardus*, here represented (Fig. 78), seek protection by inclosing their bodies in the abandoned dwelling of some univalve Mollusc; whilst others, for the same purpose, actually hollow themselves caves in the substance of stones and corals. One of these, to which M. Valenciennes has recently given the name of *Sipunculus cochlearius*, is remarkable for a habit of forming a small spiral cell in the stony substance of two very different species of coral. This animal is probably troubled with a tender skin, and, in order to prevent abrasion by the rough walls of his coral home, he lines it with a smooth vitreous matter, producing an appearance which has so deceived zoologists, that they have supposed that the corals had built their structure around some small shell, and hence, confounding the two species, described them both under the common name of *Madrepora cochlea*.



Fig. 78.—*Sipunculus Bernhardus*.

ORDER II.—SCOLECINA.

General Characters.—Of this order we have several well-known examples in the Earth-worms so common in our gardens and fields. The bodies of these animals are of a cylindrical form, somewhat pointed at the anterior extremity, and usually a little

flattened at the tail. The skin is tough, and divided into numerous segments by transverse wrinkles, and the organs of motion are reduced to the form of a double row of bristles, running down the lower surface of the body, which, instead of being placed, as in the following orders, upon prominent lobes of the skin, are usually capable of being retracted within small hollows when not in use. The mouth is unarmed, and the intestine runs straight through the body. The vascular system consists of two longitudinal vessels running along the ventral and dorsal regions of the body, and united by numerous branches. The blood is red. Like the Leeches, these worms are furnished with ciliated canals, which have been supposed to serve as organs of respiration; but their real destination appears to be still uncertain. Like the leeches, also, they are all hermaphrodites.

Divisions.—This order contains two families—the *Lumbricidæ* or *Earth-worms*, and the *Naididæ*. The former are too well known to require much description; they possess no distinct head, and are quite destitute of eyes; their bristles are hooked, and placed in little tufts in pits on the lower surface, whence they can be exerted when the animal requires their assistance. They live in holes in moist earth, and are said to be predacious animals, although popular belief charges them with the destruction of the roots of plants. Mr. Darwin has asserted that, even if these worms do some damage to vegetation, by feeding upon the tender roots of young plants, yet they amply compensate for this by the sort of tillage which they give to the soil in constantly passing through it.

It is generally supposed that the Earth-worm may be propagated by division; but this scarcely appears to be the case. It is said, however, that if it be divided across the middle, the part bearing the head will develop a new tail, although the tail will soon die; and that, if the head be cut off, the body will form a new head; but it appears that *both* portions never survive this mutilation.

This power of reproduction of lost parts is carried to a much greater extent in the *Naididæ*, which even propagate by a kind of gemmation. These animals live principally in the mud of fresh-water ponds and rivers. In their form they resemble the common Earth-worm; but their bodies are furnished, besides the ventral bundles of bristles, with a series of long spines on each side. They generally have two distinct eyes, and the mouth is sometimes armed with a long proboscis.

ORDER II.—TUBICOLÆ.

General Characters.—The worms belonging to this order, which commences the series of branchiferous *Annelidæ*, are all marine, and are distinguished by their invariable habit of forming a tube or case, within which the soft parts of the animal can be entirely retracted. This tube is usually attached to stones or other submarine bodies. It is often composed of various foreign materials, such as sand, small stones, and the debris of shells, lined internally with a smooth coating of hardened mucus; in others it is of a leathery or horny consistency; and in some it is composed, like the shells of the *Mollusca*, of calcareous matter secreted by the animal. These animals frequently live together in societies, winding their tubes into a mass which often attains a considerable size; others are more solitary in their habits. They retain their position in their habitations by means of appendages very similar to those of the free worms, and furnished, like these, with tufts of bristles and spines; the latter, in the tubicolous *Annelidæ*, are usually hooked; so that, by applying them to the walls of its domicile, the animal is enabled to oppose a considerable resistance to any effort to draw it out of its hole.

In these, as in the preceding *Annelida*, no distinct head can be recognised, and the eyes are either entirely wanting or very rudimentary. The mouth also is generally unarmed. The anterior extremity is always furnished with tentacles, which serve both as organs of touch and for the capture of prey. The nervous system is well-developed, although the longitudinal filaments generally run down the sides of the body, instead of being united by ganglia in the middle line. The branchiæ are usually confined to the head, where they appear as branched organs in the midst of the tentacles; they sometimes also occur on some of the segments of the body.

All these worms are unisexual. They deposit their eggs in a mass of mucus, which usually clings to the tube of the parent animal.

The young *Terebella*, on the first breaking out of the egg, is a small globular embryo, thickly covered with cilia. By degrees this elongates into an oval form, and the cilia collect in a band round its middle. The lengthening process continues, and in a little time a pair of small eyes make their appearance in the head, whilst a new set of cilia are developed at the caudal extremity. Still the little animal continues elongating; the cilia are reduced to a little band, like a cravat, round its neck, and a patch on the back, whilst the body exhibits traces of annulation, and single bristles begin to sprout from its sides. At last the cilia disappear altogether; the members acquire sufficient development to enable the young *Terebella* to creep along the bottom of the water. It selects a spot for its permanent abode, fixes itself, builds its house, and becomes, after its brief "Wanderjahr," a quiet, home-staying denizen of the deep.

Divisions.—In the best known family of this order, the *Sabellidae*, the branchiæ are placed on the head, where they form a circle of plumes (Fig. 79) or a tuft of branched organs. Of the tentacles, one is usually much thickened, so as to form a sort of plug, which closes the aperture of the tube when the animal is retracted. The *Serpulæ*, which form irregularly twisted calcareous tubes, often grow together in large masses, generally attached to shells and similar objects; whilst those genera which, like *Terebella* (Fig. 80), build their residences of sand and stones, appear to prefer a life of single blessedness. The curious little spiral shells, often seen upon the fronds of sea-weeds are formed by an animal belonging to this family (*Spirorbis*).



Fig. 79.—A Group of Serpulæ.

The *Hermellidæ*, some of which live amongst the oyster-beds, and often do much



Fig. 80.—Terebella.

mischief by the increase of their masses of tubes, also belong to this order.

ORDER IV.—ERRANTIA.

General Characters.—We now come to the last and highest order of the *Annelida*, comprising those animals in which the external appendages of the body attain their highest development, whilst the power of free locomotion indicates the possession of a higher degree of general intelligence than would be necessary for the sedentary animals of the last order. It must be confessed, however, that in their structure, and especially in their development, they display a very close relationship to those animals; the history of the development of the young in the two orders being so very similar, that one description will serve for both.

The head of these worms is distinctly marked, and the mouth is generally furnished with jaws of some kind, which are not unfrequently placed at the extremity of a protrusible proboscis (Fig. 81). The general structure of the lateral appendages and branchiæ has already been explained at p. 284; but the parts of which these are composed frequently exhibit the most extraordinary forms. Like the *Tubicola*, all these worms are unisexual; the ova are usually deposited upon stones or aquatic plants; but, in some instances, the mother carries them about enveloped in a slimy matter.

Divisions.—Amongst the numerous families into which this order has been divided, the one which approaches most closely, both in structure and habits, with the lower worms, is that of the *Arenicolidae*, including the common *Lob-worm*, so much used

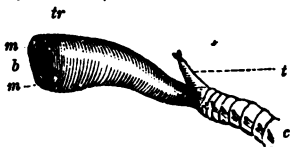


Fig. 81.—Head and Trunk of *Glyceris*; *c*, anterior portion of the body; *t*, head; *tr*, trunk; *b*, opening of the mouth; *m*, jaws.



Fig. 82.—*Arenicola Piscatorium*.

by sea fishermen as a bait. This animal is found on all sandy parts of the coast, where it bores into the sand left wet by the retiring tide; its head is large and rounded, quite destitute of eyes or tentacula, and furnished with a short unarmed proboscis. The feet are very small, and confined to the anterior part of the body; whilst the branchial tufts, which are of considerable size, are placed on each side of the middle segments.

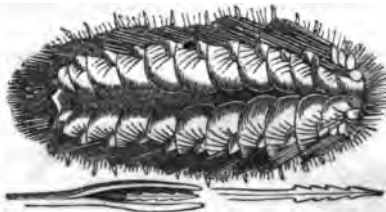


Fig. 83.—*Aphrodita hispida*.

The family of *Aphroditidae*, some species of which are known as *Sea-mice*, includes some marine animals of great beauty. In these worms the body is generally broad, or ovate, the head small, and furnished with very short tentacula; the feet large, with immense tufts of bristles and spines, often of the most remarkable forms, and exhibiting the most brilliant metallic colours. Each of these hairs (Fig. 83) is retractile within a horny sheath, which serves to protect the soft

parts of the animal from injury by its own weapons. The most remarkable peculiarity of these animals is, that their dorsal surface is entirely or partially covered by a double series of large membranous scales attached to the alternate segments, between which the beautiful bristles of the feet make their appearance. These animals generally inhabit deepish water; but numbers of them are often thrown upon our coasts after a storm.

The family of *Nereidæ* includes some elongated and distinctly annulated worms, which possess a well-developed head (Fig. 84), furnished with tentacles and eyes, and a mouth with a proboscis, which is sometimes unarmed, sometimes furnished with two or four teeth. The cirri or tentacles attached to the feet are often of considerable length,

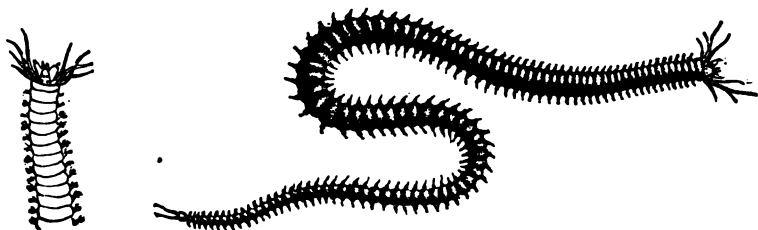


Fig. 84.—*Nereis*, with its head and some of the anterior segments.

and sometimes even annulated (Fig. 85). The animals frequently present the appearance strongly resembling that of the more elongated *Myriapoda*. The branchial tufts are but slightly developed.

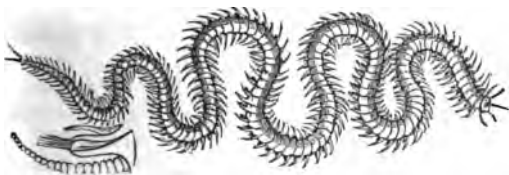


Fig. 85.—*Syllis Monilaris*, with one of its locomotive organs and setigerous appendage attached thereto.

grows to four or five feet; and others, found in the Southern Ocean, are said to attain double that length.

Zoologists also place in this order a curious terrestrial Annelide, found in the West Indies by the Rev. Lansdown Guilding, and described by him under the name of *Peripatus* (Fig. 86). In its general appearance it exhibits a most striking resemblance to the well-known *Juli*, or Millepedes; the body is distinctly annulated, the head well marked, and furnished with two jointed tentacles and eyes. Along each side of the body runs a series of soft feet, which, however, exhibit traces of annulation; and these, as in the other free *Annelida*, are terminated by tufts of bristles. This curious genus forms the family *Peripatidæ*.

The order of *Annelida Errantia* also includes another family, which appears to possess a striking affinity to the following class, the *Rotifera*. This is the family of the



Fig. 86.—*Peripatus*.

Polyophtalmida, consisting of cylindrical worms, furnished with bristle-like feet, somewhat resembling those of the *Scolecina*. Each segment of the body is said to bear a pair of eyes, whence the name given to the genus and family to which these creatures belong. The most remarkable character presented by these animals is the structure of the head, which bears a pair of lobes covered with cilia, which, like the similar organs of the *Rotifera*, can be retracted and protruded at pleasure. From these, we pass naturally to the last class of this subdivision of the Articulata, the

CLASS IV.—ROTIFERA.

General Characters.—This interesting class of microscopic aquatic animals, included amongst the *Infusoria* by Ehrenberg, is now generally admitted to belong to the Articulata division. They are animals of very diverse forms, but are always characterized by the possession of ciliated organs at the anterior extremity (Fig. 87), by means of which they produce a vortex in the water, which carries to their mouths any minute animals or plants which may be floating in their neighbourhood. The skin exhibits distinct indications of transverse wrinkles or folds, by the agency of which the animals are enabled to contract themselves to an extraordinary extent, so that they often acquire an almost globular shape. In some cases, however, the skin becomes horny, or a small quantity of silicious matter is fixed in it. In either case the skin then forms a sort of carapace, within which the little animal can retreat in case of danger. Many of them pass their lives fixed in one place like polypes, whilst others enjoy the power of swimming freely about. The free species are all furnished with some means of fixing themselves when about to feed. In some cases the tail terminates in a sort of sucker; in others, in a pair of minute forceps, by which the little creature attaches itself to its resting place.

As might be expected from their minute size, few of them exceeding a line in length, and some being no more than $\frac{1}{100}$ th of an inch, the nervous system in these animals has not been made out very distinctly. It appears certain, however, that a pair of ganglia always exists in the neighbourhood of the head, and that from these a little filament runs down each side of the body. The head also possesses from one to four eyes, usually indicated by their red colour; these, as usual, disappear in the sedentary forms; although their young, which are endowed with the powers of locomotion, possess them.

The structure of the alimentary canal is wonderfully complex, considering the

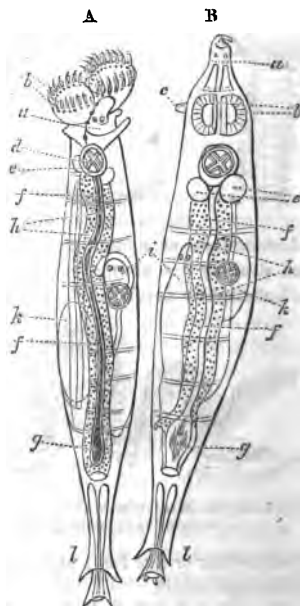


Fig. 87.—Wheel Animalcules. A, with the wheels expanded; B, with the wheels folded up and drawn in; a, the head with the eye-spots; b, the wheels; c, water-siphon; d, masticating apparatus; e, salivary glands; f, intestinal canal; g, its dilated termination; h, glandular apparatus surrounding it; i, young ones nearly complete; k, eggs; l, tail.

minute size of the creature possessing it. Within the mouth is a wide hollow, at the bottom of which the entrance to the gullet is seen; this is armed with a singular apparatus of teeth, set in motion by muscular action, and ready to seize upon any particles of food that may be carried into the mouth by the external vortex. The water introduced is sometimes carried off by a minute canal, situated close under the head; in other cases it is allowed to find its way out as it can. The teeth, in some *Rotifera*, are in the form of acute spines,—these are predaceous animals, and exhibit as much ferocity, in their way, as can be shown by creatures infinitely their superiors in size; in others they constitute small horny plates, furnished with transverse ribs; and these are usually vegetable feeders. Close to this apparatus are a pair of glandular bodies, which, apparently, discharge their secretions into the œsophagus at that point; these are regarded as salivary glands. From these the intestinal canal extends through the body, inclosed in a thick granular mass, till it nearly reaches the caudal extremity, at which point the anal opening is usually situated.

The *Rotifera* appear to be perfect self-impregnating hermaphrodites, and the ova in most of them appear to be developed within the body of the parent, until the principal organs of the young animal are quite recognizable. Their powers of reproduction are most extraordinary. Ehrenberg relates that in three days the progeny of a single specimen of *Hydatina senta* (Fig. 88), which he had isolated, amounted to no less than twenty individuals; a rate of increase which in ten days would give upwards of a million of specimens. That author adds, that “if two instead of four were produced daily by each individual, a million would be called into existence in twenty days; and on the twenty-fourth day we should have 16,777,216 animalecules.” But wonderful as is the fecundity of these animals, when placed in favourable circumstances, not less so is their power of resisting the action of drought, which might otherwise, by drying up the water of their habitations, involve the whole or the greater part of their species in destruction. It is found, however, that these little creatures may be dried completely and repeatedly, until their bodies are so brittle that the slightest touch would crush them, and that on the return of moisture they will again spring into existence, unfold their little wheels, and give rise to a fresh generation.

Divisions.—The *Rotifera* form two orders, the *Sessilia* and the *Natantia*, the names of which speak for themselves.

ORDER I.—SESSILIA.

In the sessile *Rotifera* the body is continued into a longish stalk, which is attached, by its hinder extremity, to some aquatic plant or other object. The rotatory organ, in these animals, has generally a disc-like form, with the margin more or less notched. This order includes two families, the *Flosculariæ*, which have bent spiniform teeth at

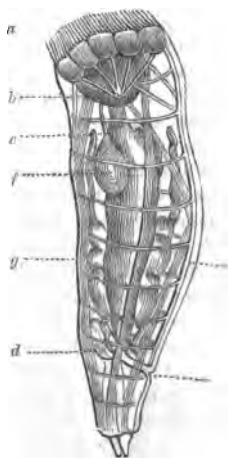


Fig. 88.—*Hydatina senta*.

a, rows of cilia; b, muscles of the jaws; c, stomach; d, enlarged termination of the intestine; e, anus; f, salivary glands; g, ovaria; h, dorsal vessel.

the orifice of the œsophagus; and the *Megalotrochida*, in which that organ is armed with ribbed plates for the trituration of the food.

ORDER II.—NATANTIA.

In this order, which, as its name implies, includes the free swimming species, the caudal extremity terminates either in a sucker-like organ, or in a small pair of forceps, by means of which the animals are enabled to fix themselves at pleasure, so as to set their rotatory organs in action. These are also divided into two families, the *Polytrocha* in which the rotatory organs take the form of several lobes surrounding the anterior extremity of the body; and the *Zygotrocha*, which possess only a pair of ciliated processes placed on each side of the mouth.

SUBDIVISION II.—ARTHROPODA, OR TRUE ARTICULATA.

General Characters.—We now come to the second subdivision of the *Articulata*, in which the division of the body into segments appears with great distinctness. This single subdivision contains a greater number of species than all the rest of the animal kingdom put together; and as the number of individuals of each species is usually enormous, the part assigned to them, in the economy of nature, is, in spite of their generally insignificant size, by no means an unimportant one. They swarm in every situation, and in every part of the earth. The plants and trees of every region nourish myriads of insects; the waters are everywhere alive with them. Their existence and its effects force themselves upon our notice in whatever direction we turn; vegetation is kept in check by their ravages; our own persons and the bodies of our domestic animals are not exempt from their attacks; whilst, as if to make up for any evils they may inflict upon our race, multitudes are constantly at work in the removal of decaying matters, which, if left to the natural progress of decomposition, would contaminate the air with their pestilential effluvia. Nor are they without some species that are of direct service to mankind. Many species of *Crustacea* are reckoned delicate articles of food; the Silk-worm, the Honey-bee, and the Cochineal insect, furnish us with valuable products; and many others contribute more or less to the comfort or the luxury of mankind.

The principal general characteristic of these animals, and that which serves at once to distinguish them from those of the preceding subdivision, consists in the division of the body and limbs into numerous distinct rings or segments, moveably articulated together, and thus forming a sort of external skeleton, which not only protects the internal soft parts, but, by giving firm points of attachment to the muscles, enables their movements to be executed with much greater rapidity and precision than those of the vermiform classes. In a few species (the *Myriapoda*, see Fig. 3) these segments (with the exception of those at the two extremities), like the indistinct rings of the *Annelida*, are mere repetitions of one another, each segment being of the same form, and bearing the same organs, as its neighbour; but the complete articulation of the segments both of the body and limbs in these animals precludes all risk of their being confounded with the members of the lower class. In the majority of the *Arthropoda*, however, some of the segments are always developed differently from the others, generally giving rise to a division of the body into three principal regions, the *head*, *thorax*, and *abdomen*; the appendages sometimes occurring along the whole series of segments; sometimes being confined to particular regions of the body.

As might be expected, from their increased capacity for motion and enjoyment, the amount of intelligence possessed by these animals is much greater than in any of the groups to which our attention has hitherto been directed; and the nervous system, of course, exhibits a corresponding advance. The general conformation of these organs has already been described (page 199, Fig. 5); and we have seen that, in the highest forms of worms, this structure is distinctly recognizable; but in the present group centralization takes place to a much greater extent, and the modifications of the original type are sometimes very considerable. As a general rule, it may be observed that, in proportion as the different segments of the body resemble each other, the nervous system approaches the original type; but that it deviates more and more from the typical structure in proportion as some of the segments preponderate over the rest.

The appendages of the segments forming the head are converted into masticating organs; and the number of these, of course, varies with the number of segments which may be supposed to form that region of the body. As these are merely metamorphosed limbs, and indeed generally exhibit their relationship to the organs of motion in their articulated structure, it is evident that, like the true limbs, they will be placed in pairs, one on each side of the middle line of the body; hence their action is always horizontal, and the opening of the mouth may be considered to be vertical. The head is also usually furnished with one or more pairs of jointed organs, called *antennæ*, which evidently act as organs of sense, and probably have different functions in different groups. Their structure often furnishes important characters for the discrimination of the minor groups into which these animals are divided.

Except in a single class (the Insects,) the segmentary appendages are developed only on the ventral surface; but in these other appendages they are also articulated to the back, forming the wings with which, as is well known, those animals are provided.

Divisions.—Numerous as these animals are, they may be divided into four classes, and these are generally very easily distinguishable. The first, the *Crustacea* (Fig. 89), possess antennæ, and are furnished with jointed appendages on all the regions of the body. Their respiration is aquatic. Some of them only exhibit the distinguishing characteristics of the class in their earlier stages. The second class



Fig. 89.—Sandhopper (*Talitrus*).



Fig. 90.—Mygale.

containing the Spiders (*Arachnida*, Fig. 90), is characterized by the absence of antennæ, by the possession of four pairs of limbs attached to the anterior portion of the body, which consists of the head and thorax fused together.

The third class, the *Myriapoda* (see Fig. 3), contains air-breathing animals furnished with antennæ, with appendages on all the segments of the body; whilst the fourth, containing the innumerable hosts of Insects (*Insecta*, Fig. 91), is characterized by its

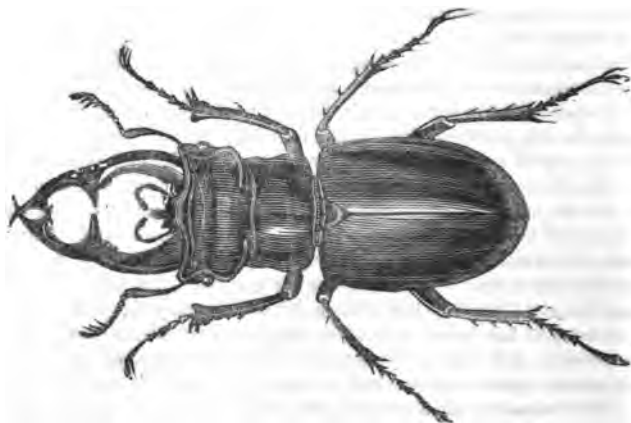


Fig. 91.—Stag Beetle.

aërial respiration; by the division of the body into three very distinct regions (of which the middle one, the thorax, bears three pairs of jointed legs, and usually two pairs of wings); and by the possession of a single pair of jointed antennæ.

CLASS V.—CRUSTACEA.

General Characters.—If this class included only the ordinary well-known forms, such as the Crab and Lobster (Fig. 92), and their allies, there would be little difficulty in giving it an exact character, which should apply to every member of which it is composed; but many of the lower forms cannot be said strictly to come under even the brief definition given above, although, in the earlier stages of their development they agree so exactly with some of the most highly organized animals belonging to the class, that it is impossible not to admit them into the same category. Our description of the class, as a whole, must consequently be liable to many exceptions.

The form of the body in these animals is excessively variable; it is usually somewhat spindle-shaped, and divided into a series of distinct rings, articulated together, and allowing of a considerable amount of movement. These segments are sometimes of nearly equal size, and furnished with nearly similar appendages throughout (Fig. 89). Sometimes a few of the segments acquire a greater degree of development than the rest, and the organs of motion are confined to these, whilst the appendages of the other segments are reduced to a more or less rudimentary condition; and in the higher forms the anterior segments become fused into a single mass, called the *cephalothorax* (Fig. 92), which bears the mouth and organs of motion. The skin is generally hardened by a calcareous secretion, constituting a complete cutaneous skeleton, within which all the soft parts of the body are inclosed; the segments are united by a thin membrane which gives flexibility to the whole armour. As the animal has no power of adding to

the size of this shell to make room for its increasing growth, it casts off its old coat



Fig. 92.—Spiny Lobster (*Palinurus*).

at stated periods, and secretes a new deposit of calcareous matter over its entire surface.

The form of the articulated appendages varies exceedingly. The first segment of the head, which is occasionally distinct from the rest, is sometimes provided with a pair of moveable stalks, on the summit of which the eyes are situated; the second and third segments bear the antennae, of which two pair are usually present. These organs generally consist of a long tapering series of short joints, supported upon two or three large articulations, similar to those of the limbs, which enable them to move freely in every direction. The appendages of the following segments are generally formed into masticating organs. They often, however, gradually approach the true limbs in their structure; and the hindmost pair or two are generally denominated *foot-jaws* by zoologists.

In the common Cray-fish (Figs. 93, 94) six pairs of these appendages are present, of which the three last are considered as foot-jaws. These are followed by the legs, the true organs of motion, which are also attached to the under surface of the thoracic

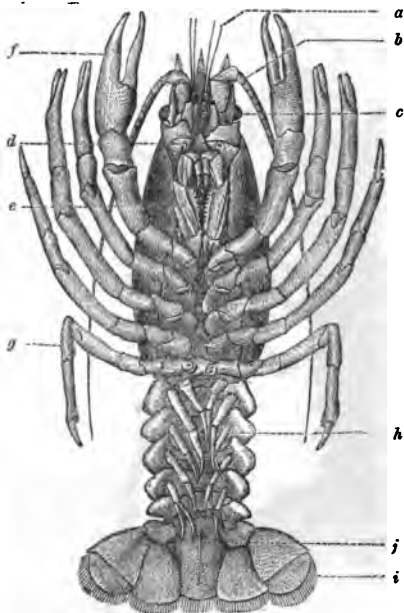


Fig. 93.

Fig. 93.—Cray-Fish: *a* and *b*, antennæ; *c*, eyes; *d*, organ of hearing; *e*, external foot-jaws; *f*, first pair of thoracic members; *g*, fifth pair of thoracic members; *h*, abdominal false-legs; *i*, tail-fin; *j*, anus.

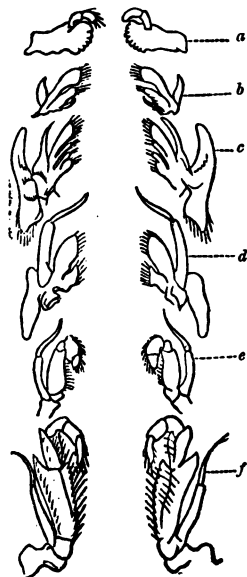


Fig. 94.

Fig. 94.—Masticatory Apparatus, composed of six pairs of appendages: *a*, mandibles; *b* and *c*, first and second pairs of maxillæ; *d e f*, three pairs of foot-jaws, gradually approaching the form of the ordinary limbs.

segments, or of the cephalothorax in the Crabs and their allies. The number of these varies, of course, with the number of thoracic segments. In the Cray-fish and Lobster (already figured), there are five pairs of these organs, the anterior pair being often developed into large pincers; and the true feet are often followed by a series of rudimentary abdominal members, which sometimes serve to protect the ova, when these are carried under the tail, and sometimes bear external branchiæ. By means of these limbs many of the *Crustacea* are enabled to run with great swiftness, whilst others have the extremities flattened so as to form fin-like organs. Many bury themselves with great rapidity in the sand, by the action of the feet, at the approach of danger; and the species furnished with pincers make use of these often-formidable weapons both to seize their prey and to attack their enemies.

The nervous system of the *Crustacea* always consists of a series of ganglia running along the ventral surface of the body, united to each other, and to a cephalic ganglion

or brain, by a pair of nervous filaments, and giving off nerves to the various organs in their neighbourhood. The development of these ganglia, however, often varies greatly in different segments; for, although in the more uniformly articulated forms the ganglia are nearly equal in size, those in which the thoracic segments are amalgamated have the whole of the nervous centres of these segments fused into a single mass, from which nerves are given off in every direction (Fig. 95). The cephalic ganglion is always situated above the cesophagus, and furnishes nerves to the organs of the senses. These are the eyes, the antennæ, and in many cases organs of smell and hearing.

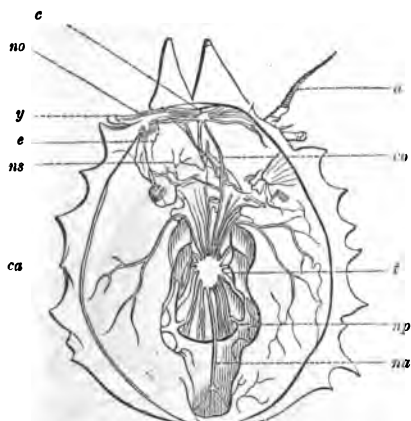


Fig. 95.—Nervous system of Crab (*Maia*).

ca, upper part of the shell laid open; a, antennæ; y, eyes; e, stomach; c, cephalic ganglion; no, optic nerves; co, cesophageal collar; ns, stomato-gastric nerves; t, thoracic ganglionic mass; np, nerves of the legs; na, abdominal nerve.

The eyes present very different degrees of development in the different orders of *Crustacea*. The lower forms possess only simple eyes, containing a single lens, surrounded by a mass of pigment, and receiving a single nervous filament. Many of the lower *Crustacea* possess only one of these organs, which is then placed in the middle of the head. In others a number of these eyes are brought together at a single point; but

each eye is still distinctly recognisable, furnished with its own lens, surrounded by its own pigment spot, and receiving its own branch of the optic nerve. In the highest *Crustacea* the visual organs become true faceted compound eyes, similar to those of insects; and these are often supported upon a footstalk, which is sometimes of considerable length (Fig. 96).

The organs of hearing (which are probably common to all the *Crustacea*, although they have been investigated principally in the highest order) are situated close to the base of the long external antennæ. In the Cray-fish (Fig. 93), they have the form of a cylindrical hollow process, which is closed internally by a thin membrane, or drum. Behind this is a vesicle filled with fluid, which receives the termination of a particular nerve. The organs of smell, which have been observed principally upon the Crabs, are in the form of cavities situated at the base of the inner pair of antennæ, and lined with a mucous membrane. The external orifice of these cavities is surrounded by fine bristles—no doubt to exclude in-

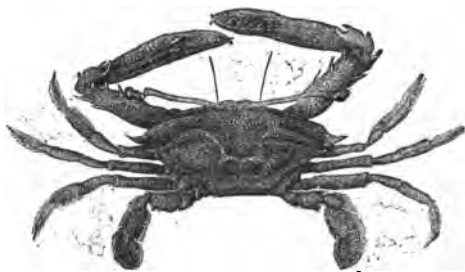


Fig. 96.—Podophthalmus.

jurious particles from the interior. The antennæ appear to be principally organs of touch; in many cases they are employed as natatory organs.

The digestive canal in the *Crustacea* generally exhibits a high degree of development. It runs from the mouth to the posterior extremity of the body, and consists of a very short œsophagus, opening into a large stomach, which is often armed with rows

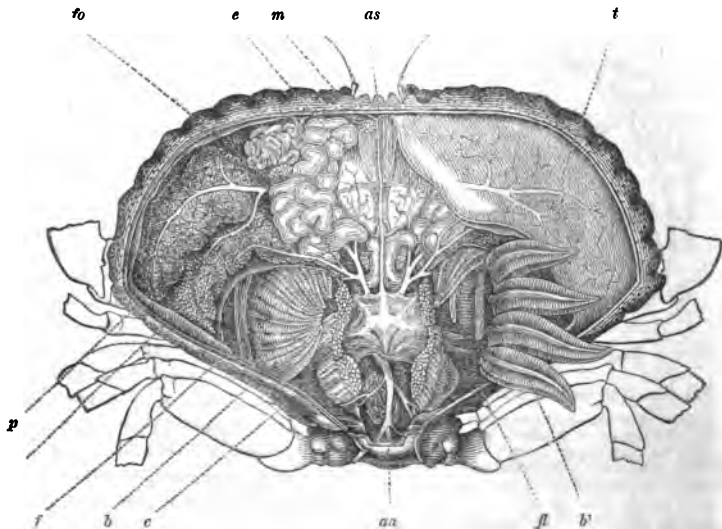


Fig. 97.—Anatomy of a Crab; the greater part of the carapace having been removed. *p*, portion of its lining membrane; *e*, heart; *as*, ophthalmic artery; *aa*, abdominal artery; *b*, branchiæ in their natural position; *b'*, branchiæ turned back to show their vessels; *fl*, lower portion of the shell; *f*, appendage of the foot-jaw; *e*, stomach; *m*, muscles of the stomach; *fo*, liver.

of teeth; from this an intestine runs to the anal opening. The liver is generally of large size.

The respiratory organs consist of branchiæ of various forms, sometimes attached to the abdominal members, sometimes inclosed within a cavity on each side of the cephalothorax, in and out of which the water passes by two openings. Circulation is effected by means of a regular system of vessels; the heart consists of a single contractile cavity, situated in the middle line of the back; the arteries, in the higher forms at least, are closed tubes; but the venous blood passes back through spaces left between the organs of the body, until it reaches peculiar cavities situated at the bases of the legs (Fig. 98), whence it passes into the branchiæ, and thence, when aerated by contact with the water, through proper vessels to the heart.

With the exception of a single order, the *Crustacea* are all unisexual animals. Their reproduction always takes place by ova, which are generally attached to the tail of the female for some time after exclusion. Indeed, in some species, the eggs are hatched in this position, and the young continue for a certain period to shelter themselves beneath the body of the mother. Their development presents many curious phenomena. In some species the young leave the egg in very nearly the same form that they are to

retain through life; whilst in others, nearly allied to these, the young animal at its first coming into the world has a form so totally distinct from that which it is destined to assume, that nothing but absolute observation could lead to a suspicion of its true parentage (Fig. 99). So different, in fact, is the appearance of the young of many of

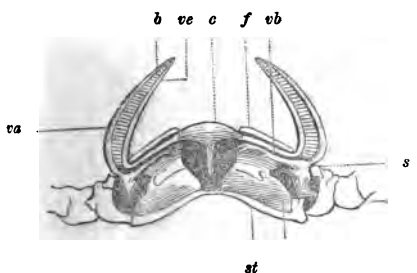


Fig. 98.—Vertical section of a Crustacean, showing the course of the blood.

c, heart; *s*, venous sinus; *va*, vessels conducting the venous blood to the gills; *ve*, vessels which collect the aerated blood from the capillaries of the gills; *vb*, branchiocardiac vessels; *f*, carapace; *st*, sternum.



Fig. 99.—Early form of Crab (*Zoea*).

the *Crustacea* from that of the mature animals, that before the connexion between them was discovered several species, and even genera, were established upon these embryonic forms. It is singular that this metamorphosis takes place amongst both the highest and the lowest members of the *Crustacea*; and that some of the latter, in which, in the mature state, most, if not all, the ordinary characteristics of the class completely disappear; yet, in their earlier stages of development, exhibit the most perfect resemblance to the most highly endowed of their relatives.

Divisions.—The immense number and variety of Crustaceous animals necessitates, as might be expected, a corresponding multiplicity of subordinate divisions. Five principal groups, or sub-classes, may be recognised. Of these, the first, the *Cirrhopoda*, is composed of animals which, until the history of their development was known, were always ranged by naturalists amongst the *Mollusca*. When mature, they are always attached to submarine bodies. Their bodies are inclosed in a shell composed of several calcareous plates, from an opening in which they protrude a bundle of articulated cirri.

The *Entomostraca*, forming the second sub-class, are generally of small size, covered with a delicate skin, and usually protected by a broad shield or a sort of bivalve shell. The *branchiæ*, when present, are attached to the feet, which, with the antennæ, are generally furnished with bristles, that render them efficient organs of locomotion. Many of them, when full grown, attach themselves, as parasites, to the bodies of other aquatic animals; and these frequently lose all resemblance to the other members of the class. The animals of the third sub-class, the *Xyphosura*, are covered with a hard calcareous carapace, and the tail forms a long, sword-shaped spine. The mouth is furnished with no jaws, and the operation of mastication is performed by the basal joints of the true feet. The fourth sub-class, the *Podophthalmata*, is at once distin-

guished by the pedunculated eyes and amalgamated thoracic segments of the animals composing it; whilst those of the fifth, the *Edriophthalmata*, on the contrary, have the eyes sessile, and the thoracic segments distinct. These sub-classes are again divided into orders, to which we must advert as briefly as possible.

SUB-CLASS AND ORDER I.—CIRRHOPODA.

General Characters.—The first sub-class includes only a single order. They are all marine animals, which, when mature, attach themselves to rocks or other submarine objects; the common Barnacle, perhaps the best known example of the order, generally selecting floating objects for this purpose, and frequently covering the bottoms of ships to such an extent as even to impede their progress through the water. The bodies of these animals are soft, and inclosed in a case composed of several calcareous plates; they formed part of the group of *multivalve shells* of the older conchologists. The limbs are converted into a tuft of jointed cirri, which can be protruded through an opening in the sort of mantle which lines the interior of the shell. The cirri are twelve in number, and beset with bristles. When the animal is alive they may be seen in continual motion, exerted and retracted every



Fig. 100.—Shell of the Barnacle.



Fig. 101.—Body of the Barnacle.

moment in search of prey. The intestinal canal is complete, furnished with a mouth and an anal opening; and the nervous system exhibits the usual series of ganglia, which we have seen to be characteristic of the articulate type. The head is marked only by the position of the mouth, which is armed with a pair of jaws; but all traces of any of the organs that we are accustomed to see at this part of the body have completely disappeared.

In their very earliest days, however, these creatures are by no means so ill provided; they are then furnished with eyes, antennæ, and limbs, and are as active as any of the minute denizens of the sea. It is only after a certain period of wandering that they fix upon a place of rest, — fix themselves, and become respectable householders. All these animals are hermaphro-

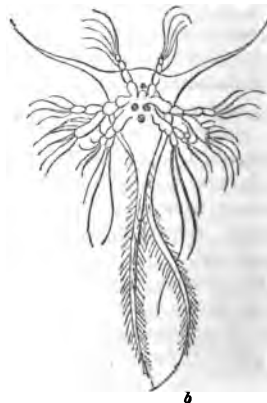
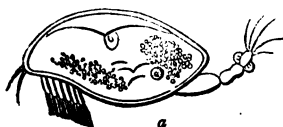


Fig. 102.—Young of Cirrhopoda.

dites; but, according to the researches of Mr. Darwin, active individuals, which he calls *complementary males*, are produced at certain periods, to assist in the impregnation of the ova of the hermaphrodite individuals.

Divisions.—The *Cirrhopoda* are divided into two families. In the first, the *Lepadida*, or Barnacles (Fig. 103), the animals are attached to their resting-place by a flexible stalk, which possesses great contractile power. The shell is usually composed of two triangular pieces on each side, and is closed by another elongated piece at the back, so that the whole consists of five pieces. The young of the Barnacles usually present the appearance represented in Fig. 102*b*.

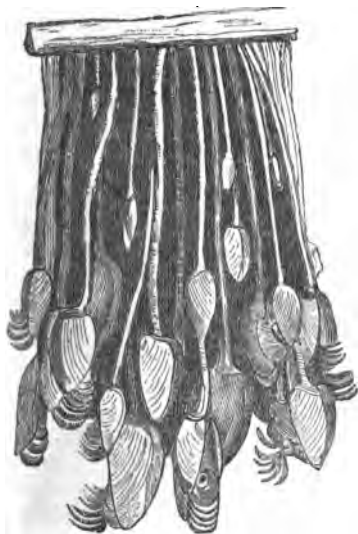


Fig. 103.—Group of Barnacles.

The second family, the *Balanida*, or Sea Acorns (Fig. 104), includes the sessile



Fig. 104.—Balanus.



Fig. 105.—Shell of Balanus.

species, whose curious little habitations may constantly be met with upon the rocks of the sea-shore, and not unfrequently upon many species of marine shells. The shell (Fig. 105) forms a short tube, usually composed of six segments firmly united together. The lower part of this tube is firmly fixed to the object on which the *Balanus* has taken up its abode; whilst the superior orifice is closed by a moveable roof, composed of from two to four valves, between which the little tenant of this curious domicile can protrude his delicate cirri in search of nourishment. In their young state the *Balanida* resemble the following group, the *Entomostraca* (Fig. 102*a*).

SUB-CLASS II.—ENTOMOSTRACA.

General Characters.—The *Entomostraca*, in general, present the characters of the class of which they form a part much more distinctly than the *Cirrhopoda*, although many of them, in their mature or reproductive state, diverge immensely from the typical form of the class. They are generally, especially in their earlier stages, provided with distinctly articulated limbs and antennæ, which are usually furnished with bristles, and employed as natatory organs.

ORDER II.—PARASITA.

General Characters.—This order is composed of numerous small animals, which, in their young state, are furnished with distinct jointed limbs, antennæ, and eyes,—organs which either disappear completely, or become greatly modified as the animal approaches maturity, when it attaches itself to fishes or other aquatic animals, and passes the

remainder of its existence as a parasite. In their mature state, the *Parasita* often present the most extraordinary forms; and in their appearance and habits they bear so little resemblance to the other *Crustacea*, that it was not until the history of their development was investigated, that their intimate connexion with that class of articulate animals was ascertained. Until very recently, zoologists considered them to be nearly allied to the *Platyelmia*, in conjunction with some of which they were formed into a class called *Epizoa* (Gr. *epi* upon, *zoon* animal), from their habits of external parasitism. They are very common on the bodies of fishes, generally attacking the branchiæ, but not unfrequently attaching themselves to the soft skin under the fins, or to the eyes, to the great inconvenience of their unfortunate victim.

Divisions.—These animals form several families, to some of which we shall briefly refer. The family *Lernæidæ* exhibits the greatest amount of degradation in its mature state. The animals composing it consist of a more or less elongated sac-like body (Fig. 106), bearing, at its anterior extremity, a proboscis, through which they suck the juices of their victim, and a pair of modified legs, by which they maintain their position upon its surface. They also frequently possess a pair of foot-jaws, which, however, are no longer connected with the mouth, but serve as additional prehensile organs. The

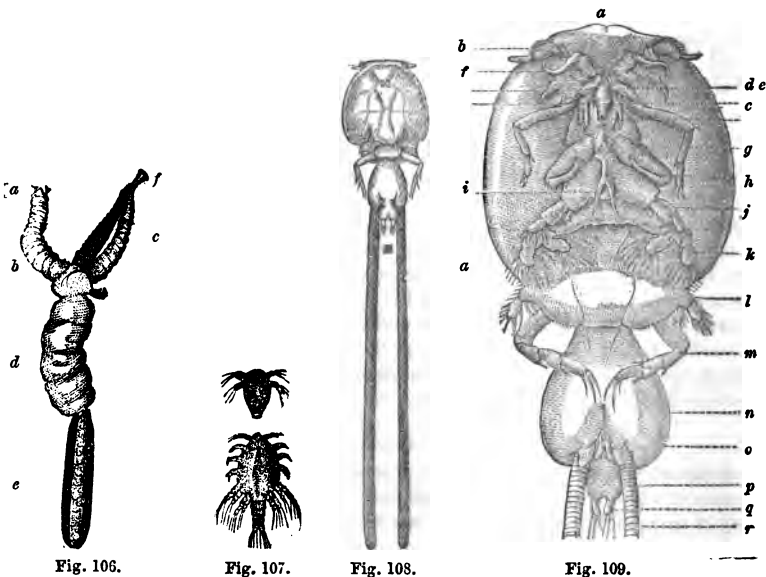


Fig. 106.—Female *Lernæa*. *a*, proboscis; *b*, thoracic segment, bearing the legs, *c*, which are united at their extremities by a sucker, *f*; *d*, abdomen; *e*, ovisacs.

Fig. 107.—Young of *Lernæa*.

Fig. 108.—*Caligus*.

Fig. 109.—Under side of *Caligus*. *a*, carapace; *b*, antennæ; *c*, sucker; *d e*, jaws; *f g h*, foot-jaws; *i*, a forked central appendage; *j k l m*, legs; *n*, second segment; *p*, abdomen; *q*, fins; *r*, tubes.

proboscis is usually buried in the substance of the unfortunate host, whose delicate vessels are wounded by a pair of pointed organs which it contains. The young of the

Lernaeida (Fig. 107) are exactly like those of the next order of *Entomostraca*, the *Copepoda*.

In the *Dicholestida* the body is more distinctly annulated, and the anterior segment bears four antennae, of which one pair is slender and thread-like, whilst the others are stout, and furnished with a claw-like extremity, serving as a prehensile organ. In the *Caligida* (Figs. 108, 109) the structure is much more complicated; the body is divided into two parts, of which the anterior, which is by far the largest, and is covered by an oval carapace, bears two pairs of antennae, a sucker, three pairs of foot-jaws, and four pairs of thoracic legs—three formed for swimming, and one for walking. The abdomen consists of a small lobe at the apex of the second segment. It bears a pair of small fin-like appendages; and from each side of its base springs a long tube, which apparently serves as an ovisac.

In the *Argulida*, one species of which, the *Argulus foliaceus* (Fig. 110), is very common upon various fresh-water fishes, the body is of much the same general form as in the *Caligida*, and the anterior segment is in like manner covered by a large carapace. The second pair of foot-jaws is here converted into a pair of curious sucking discs (Fig. 110, 2), by which the creature adheres to any object. Between these the jointed rostrum takes its rise. The four pair of thoracic legs are fringed with bristles, and converted into powerful natatory organs, by means of which the *Argulus* swims about with great rapidity. Unlike the other parasites, it does not remain constantly attached to its victim, but only adheres to it while actually engaged in sucking. It possesses no ovisacs, and the eggs are deposited upon aquatic plants.

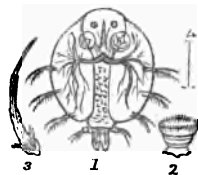


Fig. 110.—*Argulus foliaceus*. 1, the animal magnified; 2, one of the large anterior sucking-feet; 3, the rostrum; 4, natural length.

ORDER III.—COPEPODA.

These animals present the closest affinity with those of the preceding order, particularly in their earlier stages. They are minute animals, with the body divided into distinct segments, of which the anterior (forming the cephalothorax) bear two pairs of antennae, one or two eyes, the mouth, with its jaws, and two pairs of foot-jaws. The five following segments bear a similar number of pairs of feet, furnished with bristles,



Fig. 111.—Larva of the Cyclops.



Fig. 112.—*Cyclops*.

and adapted for swimming; and the remainder, constituting the abdomen, form a sort of jointed tail, terminated by a tuft of bristles. They appear to possess no distinct respiratory organs; and the ova are carried in sac-like organs attached to the abdomen of the mother. These animals occur in countless swarms in all waters, whether salt or fresh; and, minute as they are, one species is said to constitute the principal food of the Antarctic Whale.

The best known form is the genus *Cyclops* (Fig. 112), specimens of which may be found in every stagnant pool; it is the type of the family *Cyclopidae*, characterised by the possession of a single eye. In the *Cetochilidae* there are two of these organs.

ORDER IV.—OSTRACODA.

General Characters.—In this order, composed of animals generally of very minute size, the body, which strongly resembles that of the *Copepoda*, is always



Fig. 113.—Cypris
Vidua, magnified.

inclosed in a little bivalve shell, the feet and antennae being protruded between the lower edges of the valves. These little shells so closely resemble those of minute bivalve Mollusca, that those of some of the larger species have actually been described by conchologists as the coverings of



Fig. 114.—Polyphemus Stag-
norum.

animals belonging to that class. The antennae are often curiously branched; and the hinder extremity is usually produced into a sort of tail, which is seen in constant action when the animal is in motion.

Divisions.—This order forms two families—the *Cypridae*, in which the body is entirely inclosed within the shell, of which the genus *Cypris* (Fig. 113) is an example; and the *Daphniadae*, in which the head is protruded beyond the shell. In the *Polyphemus* (Fig. 114), belonging to this group, the head, which is large, is almost entirely occupied by an enormous eye, giving the creature a most singular appearance.

ORDER V.—PHYLLOPODA.

General Characters.—In this order we meet with animals generally of larger size than those comprised in the preceding groups. They consist of a considerable number of segments, furnished with foliaceous feet, serving both as natatory and respiratory organs. Some of them are covered by a carapace or a bivalve shell, whilst others are destitute of this protection. The head is usually quite distinct from the following segment, and bears two large eyes and two pairs of antennae, which are often of very singular forms. The mouth is furnished with jaws.

Divisions.—This order is divided into two families. In the first, the *Apodidae*,

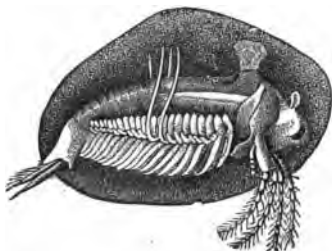


Fig. 115.—Limnadia.

the body is protected by a carapace, which often takes the form of a bivalve shell. The animals are frequently of considerable size; and the number of feet in the typical genus *Apus* (Fig. 116), is as great as sixty pairs. A singular circumstance, connected with this animal, is that it sometimes makes its appearance in great numbers in ponds that have been dry for some time, as soon

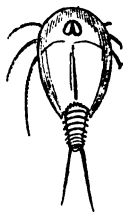


Fig. 116.
Apus Montagu.

as they are filled up by heavy rains. In the genus *Apus* the carapace is one piece, completely inclosing all the anterior portion of the animal. In the *Limnadiae* (Fig. 115), also belonging to this family, it forms a sort of bivalve shell.

The second family includes the naked species, or those which are not provided with a carapace. They are called *Branchipodida*, from the name of the typical genus, *Branchipus* (Fig. 117), an animal which is often found after heavy rains in cart ruts and other small pools. Another species, the *Artemia salina* (Fig. 118) inhabits a still more curious situation, namely, the salt pans at Lympington, where it is usually found in those pans in which the evaporation of the water has proceeded to a considerable extent.



Fig. 117.—*Branchipus Stagnalis*.

This is also, probably, the proper position for a singular order of fossil Crustacea, the well-known *Trilobites* (*Trilobita*), of which vast numbers occur in some of the earlier strata of the earth's

crust. Their general form is well shown in the annexed figure of *Calymene Blumenbachii*; they possessed well formed, compound, faceted eyes, which are frequently well preserved in the fossil state. The body is usually divided into three regions, of which the first and last are commonly in the form of semicircular plates, whilst the middle



Fig. 119.—*Calymene Blumenbachii*.

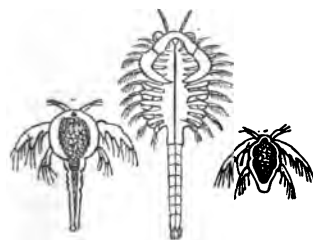


Fig. 118.—*Artemia Salina*, in different stages of growth.

portion exhibits distinct segmentation, and by its flexibility enabled the animal to double itself up in the manner of the common Woodlouse. These animals are now quite extinct, although during the period of the deposition of those ancient strata in which their remains are found, they were almost the only representatives of the class *Crustacea*.

SUBDIVISION III.—XYPHOSURA.

This subdivision includes only a single order:

ORDER XYPHOSURA.

The order *Xyphosura* consists only of a single genus, the *Limuli*, or *King-Crabs* (Fig. 120), which, from the locality inhabited by the commonest species, are frequently termed *Molucca Crabs*. They are amongst the largest of crustaceous animals, sometimes measuring as much as two feet in length.

The body of these animals is composed of two divisions—an anterior, crescent-shaped piece (c, Fig. 120), or carapace, inclosing the cephalothorax with its organs; and a posterior, somewhat hexagonal piece, formed by the coalescence of the abdominal segments. From the posterior extremity of this second division of the body projects a long, spine-like tail, which exhibits no trace of segmentation. The upper surface of the body is very convex; the lower surface, on the contrary, is very concave in the middle, forming a hollow, in which the feet are lodged.

The upper surface of the carapace is marked by three ridges (see Fig. 120); the middle terminates anteriorly in a small tubercle, on each side of which is a minute simple eye; but the creature is also furnished with true compound faceted eyes, placed

one on each side, on the outside of the two lateral ridges. Three sides of the abdominal plate are confined within the posterior margin of the carapace; of the others, two are notched and furnished with moveable plumose spines, and the caudal spine is capable of motion in every direction. The mouth, which is situated near the middle of the lower surface, is completely destitute of true jaws; but the basal joints of the five pairs



Fig. 120.—*Limulus*.

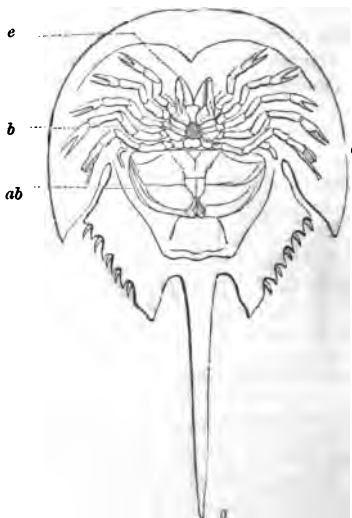


Fig. 121.—Under surface of *Limulus*.

of legs (*b*, Fig. 121), which are attached close to the buccal aperture, are armed with horny spines, forming very efficient organs of mastication, whilst their extremities, being converted into prehensile claws, are employed in the conveyance of food to the mouth. Immediately in front of the mouth are placed a pair of short jointed antennae (*e*, Fig. 121), which also bear a small pair of forceps at their extremity.

The concavity of the abdominal plate is occupied by six pairs of fin-shaped abdominal feet (*ab*, Fig. 121), of which five pairs are furnished with branchiae, whilst the first pair, which is destitute of those organs, forms a sort of cover for the rest. The anal opening is situated close to the base of the caudal spine.

These singular animals, which appear to be most nearly allied to the Phyllopodous *Entomostraca*—but which also in many points, especially in the structure of their eyes, approach the true Crabs—are found in a very limited area; they occur only on the shores of tropical Asia, the Asiatic Islands, and on the western coasts of tropical America. The young closely resemble their parents, except that, at their first escape from the egg, they possess only two pairs of branchial feet, and are quite destitute of a tail.

SUB-CLASS IV.—*EDRIOPHTHALMATA*.

General Characters.—The animals belonging to this sub-class have the head distinct from the thoracic segments, which are also separate, and never amalgamated into a single mass (the so-called *cephalothorax*), which occurs so generally in the other *Crustacea*. The head always bears a pair of eyes, which are never pedunculated; they usually consist of a number of simple eyes crowded together into one spot, although some species possess regular compound eyes. The mouth is furnished with jaws, and with a single pair of foot-jaws; and these are usually followed by seven pairs of legs, to which the branchial organs are attached.

Divisions.—The *Edriophthalmata* form three orders, characterized principally by the structure of the feet and abdomen. In the first, the *Læmodipoda*, the abdomen is rudimentary, or in the form of a minute tubercle without appendages; in the *Amphipoda*, the abdomen is well developed, and furnished with limbs, but the branchial organs are confined to the thoracic legs; whilst in the *Isopoda* the abdominal legs appear to be the organs of respiration.

ORDER *LÆMODIPODA*.

General Characters.—These animals are at once distinguishable by their rudimentary abdomen, which usually forms a very inconspicuous part of their bodies. The head is small, furnished with four antennæ, and usually bears the first pair of legs; the mouth is armed with well-developed jaws, and with a pair of foot-jaws bearing long palpi. Of the seven pairs of legs usually present, two are sometimes wanting—their places being taken by small tubercles or vesicles connected with the process of respiration; this change usually takes place on the third and fourth segments, and similar vesicles also occur on the second and third. The legs of the first and second pairs are terminated by a raptorial grasping organ similar to that of the well-known *Mantis*, or *Praying insect*; the others are usually armed with sharp moveable hooks. The ova are received into a sort of pouch, formed of several leaves, which are attached to the footless segments.

Divisions.—This curious little order includes only two families. The *Cyamidae*, or *Whale-lice* (Fig. 122), which infest the different species of cetaceous *Mammalia*, form

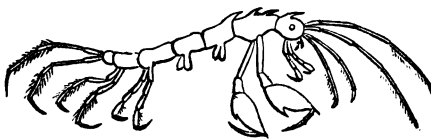


Fig. 122.—*Caprella Phasma*.



Fig. 123.—Whale-Louse (*Cyamus Balaenarum*.)

the first of these. They have a broad body, with a small head, and a pair of large jointed antennæ. The other antennæ, and the first pair of legs, are very small; but the second pair are of large size, and very powerful. The legs of the third and fourth segments are converted into long tubular branchial vesicles; but those of the last three segments resemble the second pair in their strength, and in the sharpness of

their claws. These animals often infest the whales in such vast numbers that their victim may be recognized at a distance by the whitish tint of his skin.

In the second family, the *Caprellidae*, all the proportions of the body are reversed; instead of being broad and flat, it is long, slender, and nearly cylindrical, and the limbs undergo a corresponding extension in the same direction. The antennæ are frequently of considerable length; and the two first pairs of feet exhibit a striking resemblance to those of the *Mantis*. One genus has all the segments furnished with legs; in another (Fig. 123), the third and fourth bear small vesicular organs in place of limbs.

ORDER AMPHIPODA.

General Characters.—This order also consists of animals mostly of small size, none of them exceeding two inches in length. They usually live free in the water or burrow in sand; a few species are parasitic on fishes. The head is completely separated from the first thoracic segments, and usually bears four antennæ, which are sometimes of considerable length. The mouth is furnished with jaws and a pair of foot-jaws. The thorax consists of six or seven segments, each bearing a pair of legs, which are usually furnished with leaf-like branchial appendages, at their bases. In the females of some species the legs also bear peculiar appendages, which serve to keep the eggs under the body. The abdomen is well-developed, and furnished with limbs of various forms, sometimes adapted for swimming, sometimes for leaping—a movement in which some of the *Amphipoda* display great agility. They always lie upon their sides in swimming.

Divisions.—This order also includes two families—the *Hyperidae* and the *Gammaridae*. The first is characterised principally by the small size of the foot-jaws, which are not furnished with palpi or similar organs. The legs are usually unequal in size; and one or two pairs are often remarkably large, and converted into powerful prehensile organs. The *Gammaridae* are characterised by the large size of the foot-jaws, which cover the whole mouth. The common *Talitrus locusta*, or Sand-hopper (Fig. 89), which may be met with in thousands upon the sands of our shores, is a well-known example of this family. Although its length is not much more than half an inch, it can leap several inches into the air, and the facility with which it escapes pursuit by burrowing into the soft wet sand, is truly wonderful. Another species, *Gammarus pulex* (Fig. 124), is found commonly in fresh water, and is scarcely inferior to its marine relative in agility.

The *Coryphium longicorne* (Fig. 124), remarkable for its long antennæ, is not less so for its singular habits. It is found at Rochelle, where it burrows in the sand, and



Fig. 124.

Fig. 124.—*Gammarus Pulex*.

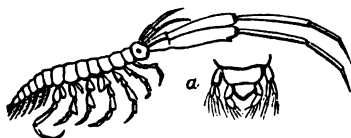


Fig. 125.

Fig. 125.—*Coryphium Longicorne*; a, terminal segment of the tail.

wages constant war with all other marine creatures of moderate size that come in its way. To discover their prey, they beat about in the mud with their large antennæ. The comparatively gigantic size of many of the *Annelida* does not protect them from

attack; a suitable number of the little warriors make common cause against the enemy, who soon succumbs to their united efforts.

ORDER ISOPODA.

General Characters.—This order includes the greater part of the *Edriophthalmata*, and the animals composing it exhibit a great variety of form and structure. The body is sometimes of an oval, sometimes of an elongated form, convex above and flat beneath; the head (Fig. 126 c) is small, distinctly separated from the first thoracic segment, and bears a pair of round eyes, usually formed of a collection of simple eyes, but sometimes truly compound. The antennæ are often of considerable length, and the jaws are well-developed. The thorax consists of seven segments (t^1-t^7), each of which bears a pair of feet ($p-pp$); these are usually similar in form, nearly equal in size, and furnished, in the female, with basal plates for the protection of the eggs. They never bear branchial plates as in the preceding orders. The abdomen (ab) is well-formed, and consists of six segments, which are often, however, more or less amalgamated together. The abdominal legs are furnished with a pair of large oval plates, of which the inner is of a soft consistence, and acts as a branchial organ; the sixth pair, however, usually forms a sort of cover, which can be folded over the others for their protection. In the air-breathing species, of which the common Woodlouse (Fig. 126) is an example, the branchial plates of the hinder abdominal legs are quite rudimentary, whilst those of the anterior ones are well-developed. Into these the air obtains access by small apertures at their base.

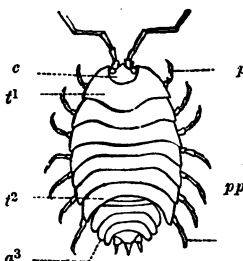


Fig. 126.—Woodlouse (*Oniscus*).

Divisions.—This order is remarkable, from its presenting, in its lowest forms, animals as thoroughly parasitic in their habits as the *Crustacea* of the Entomostracous order *Parasita*; whilst at the opposite extremity of the scale, the air-breathing *Isopoda* appear to make a very close approach to the *Myriapoda*. M. Milne Edwards has divided the *Isopoda* into three sections, denominated, from their habits, *Cursorial*, *Natatorial*, and *Sedentary* Isopods. The latter comprises those species which are fitted for a strictly parasitic existence, being furnished only with clinging feet. We include only a single family in this section, the *Bopyridæ*, which live in the branchial cavity of Shrimps. The females of these animals are scarcely more recognizable as Crustaceans than the Cirrhopodous Barnacles or Acorn shells. They are of an irregularly oval form, furnished with fourteen feet, but quite destitute of eyes. The males are about a sixth part of the size of the females, and present very much the form of an elongated Woodlouse; but the feet are very short, and the abdominal segments are amalgamated into a single plate.

The *Natatorial Isopoda* have the last pair of abdominal feet, terminated by horizontal plates, which form, with the extremity of the abdomen, a regular caudal fin. This section includes two families. Of these the *Cymothoidæ* (Fig. 127) are parasitic upon fishes, apparently having an especial predilection for their tails. They have small heads, with short antennæ; and the legs are short, and terminated by hooks. In the second family, the *Sphæromidæ*, the body is usually oval and very convex, sometimes nearly hemispherical; the head is large, with four longish antennæ, and the feet are slender,

and fitted only for walking. The five first abdominal segments are fused together; but the last is free and of large size, forming, with the lateral fins, a powerful natatorial organ. These animals all live in the sea, especially on rocky coasts. Like the Woodlice they are able to roll themselves up into a ball.



Fig. 127.—*Anilcerus*.

The Cursorial, or walking Isopods, are distinguished from the preceding by the absence of the fin-like expansion of the posterior extremity of the body. The first family, the *Idotheidae*, is distinguished by the development of the posterior abdominal feet into a pair of flat appendages, which can be made to cover the branchiiferous feet completely. These animals all live in the sea; they are of an elongated form, and the outer antennæ are usually of great length. The second family, the *Asellidae*, resembles the preceding in many respects, but the appendages of the last abdominal segment are styloform. One species of this family, the *Limnoria terebrans*, a little creature about the sixth of an inch in length, is exceedingly destructive to wood-work immersed in the sea. It bores into timber in every direction, apparently for the purpose of feeding upon it, and has often produced great alarm by its ravages. Some species of this family also live in fresh water.

The last family, the *Oniscidae*, including the well-known *Oniscus*, or Woodlouse (Fig. 126), and many similar animals, is characterized by the adaptation of its members to a terrestrial existence. The outer antennæ alone are visible, the inner pair being usually very minute. The body is generally oval, with the rings very distinct; and the legs are formed exclusively for walking. Nearly all these animals live on land, in damp places, under stones, dead leaves, and moss; some of them are not uncommon in cellars. When alarmed, they roll themselves up into a ball (Fig. 128), presenting nothing but the smooth, convex surface of their scaly armour to their enemy.



Fig. 128.—*Armadillo pustulatus*.

SUBCLASS V.—PODOPHTHALMATA.

General Characters.—The animals forming this sub-class are distinguished by many peculiarities from those of the preceding sections, and undoubtedly present the characteristics of their class in the greatest perfection. They are easily recognized by the position of the compound eyes at the extremity of a pair of moveable stalks (Fig. 129 *y*), which are often of considerable length (Fig. 96). The head and thorax are generally amalgamated into a single piece, called the cephalothorax, which bears the antennæ, the eyes, the mouth with its jaws (Fig. 94), and the feet (Fig. 129 *p*); of the latter organs five pairs are usually present, besides one or more pairs of foot-jaws. The remaining segments are generally quite distinct, forming a jointed abdomen, which is frequently terminated by a fan-like caudal fin (*n*). The abdominal legs are sometimes organized for swimming; but rarely, as in some members of the preceding sub-class, bear respiratory appendages, the branchiæ being usually inclosed within a cavity on each side of the cephalothorax, as already described.

Divisions.—The *Podophthalmata*, or stalk-eyed Crustacea, may be readily divided into two orders, characterized by the structure of their respiratory apparatus. In the

first, the *Stomapoda*, the branchiæ, when visible, hang freely from the abdomen as

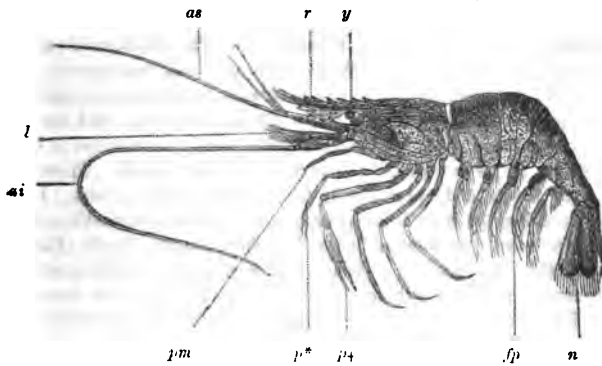


Fig. 129.—Prawn.

as, antennæ of the first pair; *ai*, antennæ of the second pair; *l*, lamellar appendage covering its base; *r*, rostrum, or frontal prolongation of the carapace; *y*, eyes; *pm*, external foot-jaw; *p1*, first thoracic member; *p2*, second thoracic member; *fp*, false legs, or swimming members of the abdomen; *n*, tail-fan.

filiform organs, at the base of the abdominal feet; whilst in the second, the *Decapoda*, they are always inclosed in cavities of the cephalothorax.

ORDER STOMAPODA.

General Characters.—This order is composed of some singular animals, which appear to have relations with all the other groups of Crustacea, and, of course, exhibit a corresponding diversity of structure amongst themselves. The thoracic segments are sometimes completely covered

by the carapace; whilst, in other forms, the carapace only covers one or two segments. The segment bearing the eyes and antennæ is always distinct. The mouth is furnished with jaws, and usually with a single pair of foot-jaws; these are followed by seven or eight pairs of true feet, of which the anterior are often converted into prehensile organs, whilst the posterior are usually organized for swimming. The prehensile feet are never terminated

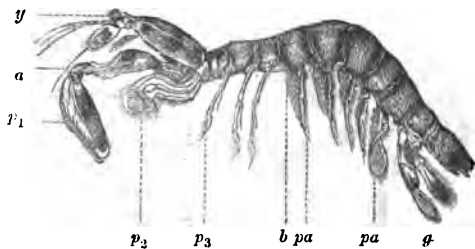


Fig. 130.—Squilla.

y, eyes; *a*, antennæ; *p1*, first pair of legs; *p2*, second pair of legs; *p3*, three last pairs of thoracic legs; *pa*, abdominal pro-legs; *b*, gills; *g*, fin-like members.

by nipping claws, like those of the Lobster. The abdominal feet are usually leaf-like organs; they bear, attached to their bases, tufts of branched filaments, which act as

respiratory organs; these, however, are sometimes altogether wanting, and are very rarely attached to the thoracic legs.

Divisions.—The *Stomapoda* form three families. The *Phyllosomidae* are animals of an extraordinarily flattened form, with the shell thin and transparent; the body is apparently divided into two parts,—a longish or oval cephalothorax, bearing the eyes, which are supported upon long slender stalks, the short antennæ, and the mouth; and a second piece, composed of the thoracic segments, which bears seven or eight pairs of long slender feet on its margins. The abdomen is very small. These animals are oceanic in their habits, and are generally found in the southern seas. In the second family, the *Squillidae*, the body is elongated, and bears a considerable resemblance to the well-known insect, the *Mantis*; hence the typical genus *Squilla* (Fig. 130) is frequently called the "Sea Mantis." Some of them attain the length of a foot or more; but their average size is about three or four inches. The eyes are mounted on short foot stalks. The antennæ are of moderate length, and the outer pair have an oval plate at the base. The carapace is small, and leaves three segments of the thorax uncovered; these bear three pairs of swimming feet. The mouth is furnished with distinct jaws, and with five pairs of large foot-jaws. The second pair, especially, are of extraordinary size, forming large raptorial organs; whilst the others are furnished with a large vesicular joint, against which the terminal claw can be applied in the same manner as the last joint of the anterior pair. All these feet are so arranged that their extremities can be easily brought in contact with the mouth, so as to hold the prey in a convenient position for the action of the jaws. The abdomen is furnished with six pairs of feet, of which the last pair are formed into fin-like organs, which, with the extremity of the powerful abdomen, constitute an excellent natatory organ. The other abdominal feet bear the branchiæ, which consist of bundles of branched or plumose filamentous organs.

The third family, the *Mysidae*, forms a distinct step towards the following order; the animals composing it presenting, in fact, so close a resemblance to the true Shrimps, that by many authors they have been placed with them. In the form of the body

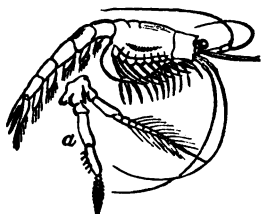


Fig. 131.—*Mysis Vulgaris*, about twice the natural length.
a, one of the bifid legs.

they exactly resemble the Shrimps; the thoracic segments being completely inclosed in a carapace, and the abdomen bowed and furnished at its extremity with a caudal fin of five plates. The thoracic feet vary in number. They are usually furnished with long, jointed appendages, which appear like so many additional limbs. The branchiæ are sometimes attached to the abdominal legs, sometimes to the thoracic legs, and sometimes they are wanting altogether; but they are never inclosed, as in the following order, within the carapace. These animals have received the name of "Opossum Shrimps," from the curious pouch, formed of plates attached to the abdominal legs, in

which the female protects both her eggs and young, until the latter have attained a considerable development. They occur but sparingly in the European seas, but swarm in profusion in some parts of the world, especially in the Arctic Ocean, where they are said to constitute an important portion of the diet of the whale.

ORDER DECAPODA.

The general characteristics of the animals of this order have been already so fully described, that we need only say here, that it includes all those stalk-eyed *Crustacea*, in which the whole of the thoracic segments are united with those of the head into a single mass (the *cephalothorax*), incased in a common shell, with no traces of segmentary division (the *carapace*), and which have the branchial organs inclosed within a cavity on each side of the cephalothorax. The true thoracic legs are almost always ten in number; whence the name of the order. It includes an immense number of species, generally of considerable size, when compared with the other *Crustacea*; and these vary so greatly in their form as to have given rise to the establishment of three distinct sub-orders, characterised principally by the degree of development of the abdominal region.

SUB-ORDER I.—MACRURA.

General Characters.—In this order, including the *Long-tailed Decapod Crustacea*, the abdomen is largely developed, generally longer than the cephalothorax, capable of being extended backwards, and furnished at the extremity with a fan-shaped caudal fin, which is of great service to the animal in the operation of swimming. The first five segments of the abdomen are furnished with laminar or cylindrical legs, to which the ova are attached by a sticky matter after expulsion from the ovaries. The two last segments with broad plates, which, with a similar plate at the extremity of the last segment, form the five-fold tail fin. The antennæ—the outer pair especially—are usually of considerable size, sometimes even exceeding the body in length, and the feet are often terminated by a pair of nipping claws, of which those of the anterior pair are sometimes of great size and power. The *Macrura* undergo but little change in their progress to maturity; the young, on first escaping from the egg, usually presenting a very close resemblance to their parents.

Divisions.—The *Crangonidae*, including the well-known Shrimps and Prawns (Fig. 129), form the first family of the *Macrura*. They are distinguished by the possession of a large oval or triangular appendage (Fig. 129 I), which covers the base of the first joint of the outer antennæ. In their general appearance they all present a considerable resemblance to the common Shrimp, which is too well known to need description. They all inhabit salt water, and generally occur in numbers together, on sandy coasts; and in spite of their small size, they are everywhere in great request as articles of food. The second family, the *Astacidae*, to which the common Lobster belongs, is distinguished from the preceding by the small size of the appendage at the base of the outer antennæ, besides many other differences in form and structure. The anterior pair of feet is always much larger than the others, and armed with powerful nippers. Some of these animals live in fresh water. These are of smaller size than the marine species, but are also eaten in great numbers by the inhabitants of the neighbourhoods where they occur. The *Astacus fluviatilis*, or Cray fish, is very common in our rivers; and may be seen for sale, boiled as red as a Lobster, in many inland towns. In the remaining *Macrura*, the base of the outer antennæ is not covered by a moveable plate; but the animals generally exhibit a very close resemblance in form to the *Astacidae*. In the *Thalassinidae* the shell is of a somewhat horny consistence; the breast is very narrow, and the anterior nipping claws of large size. The last family, including perhaps the largest *Crustacea*, is that of the *Palaemonidae*, of which the Spiny Lobster

is an example. These are [powerful animals, with very hard shells. The breast is broad, the outer antennæ usually very long, and the anterior feet are rarely furnished with nippers, and these, when present, are small. All these animals inhabit the sea, where they usually frequent deepish water, not far from the shore. Many of them are used as food in various countries. The *Palinurus*, or Spiny Lobster, often weighs as much as twelve or fifteen pounds. It was in great esteem amongst the ancient Romans, who denominated it *Locusta*.

SUB-ORDER II.—ANOMURA.

General Characters.—The second sub-order of the *Decapod Crustacea* includes a number of animals which appear to hold an intermediate position between the Long-tailed forms just described and those in which the abdominal segments are least developed—the third sub-order *Brachyura*. They partake, to a great extent, of the characters of both groups, sometimes approaching one, sometimes the other; so that it becomes almost equally difficult either to distribute them amongst the Long and Short-tailed forms, or to find characters by which they may be distinguished from the other two groups.

They are distinguished from the *Macrura* principally by the form of the abdomen, which scarcely ever possesses the fan-like fin so characteristic of those animals, and never bears natatory feet; whilst they differ from the *Brachyura* in nearly always having appendages attached to the last abdominal segment but one, which are wanting in the latter sub-order. The abdomen is sometimes bent under the body like the tail of a crab, sometimes extended backwards in a line with the body. The inner pair of antennæ is generally of moderate size, and the outer pair of considerable length. The three first pairs of feet are always well-formed, and the anterior pair are generally furnished with powerful nippers. The fourth and fifth pairs are generally small, and frequently rudimentary. In the latter case they are sometimes attached to the back. The development of the young appears to resemble that of the *Brachyura*; the newly hatched young, as far as yet observed, being very like that of the common Crab.

Divisions.—In the first family of this sub-order, the *Pagurida*, or Hermit Crabs, the abdominal portion is quite soft, forming a sort of cylindrical fleshy mass behind the shelly cephalothorax. The latter bears well-developed feet, of which the anterior pair is usually converted into formidable nippers. As the comfort of the animal would be materially interfered with were this soft, worm-like appendage constantly exposed to be grabbed at by every passing fish who might take a fancy to it, he usually seeks some shelter for his tail, and the habitation selected is generally the shell of some univalve Mollusk. Into this spiral home the Hermit Crab is coiled, and retains himself in this position by means of a sucker at the extremity of his tail, assisted by two or three rudimentary feet, which are developed upon the abdominal sac; and so firmly does he adhere to his castle, that he will allow himself to be torn to pieces rather than let go his hold. By protruding his body, with its three pairs of legs, from the orifice of the shell, the little Hermit is enabled to walk with ease upon the sandy beach in search of his prey; but the moment danger threatens him, he disappears again into his cell, the orifice of which is then occupied by one of his claws, which is always larger than the other. As the Crab does not possess the same power of adding to the size of the domicile that was enjoyed by the original tenant, he is compelled, from time to time, to change his residence for one a little larger, and often appears almost as difficult to please as a human householder in the same predicament. Often they may be seen crawling

about amongst the empty shells just thrown upon the beach, trying one after another, until they meet with one uniting all the conditions requisite for Crustacean comfort; but, until this great object of their search is attained, always returning to their old house after each unsuccessful trial. It is said, indeed, that when two of them happen simultaneously to cast a longing eye upon some particularly suitable residence, they often engage in a fierce battle for the possession of the coveted object, which the victor carries off in triumph.

Several species of Hermit Crabs inhabit our shores, and may be frequently found in the pools left by the retiring tide, by any one who will take the trouble to look for them. A curious species belonging to this family, the *Birgus latro*, inhabiting the Isle of France, which protects its soft body in holes in the earth at the roots of trees, is said to feed upon cocoa-nuts, and even to climb up the trees in the night to nip off the fruit.

In the *Hippida* (Fig. 133), the fleshy abdomen disappears, and its place is taken by a jointed tail, furnished with a pair of moveable appendages attached to the last point but one. This tail is sometimes extended behind, but generally bent under

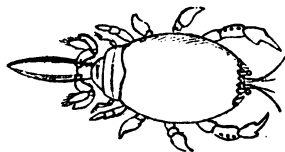


Fig. 132.—*Remipes Testudinarius*.



Fig. 133.—*Hippa*.

the breast (Fig. 132), as in the true crabs, and never terminated by a fan-like fin. These animals generally live in the sand, where they bury themselves with great facility by means of their flattened feet. The family *Porcellanidae* includes some small Crabs, which, from their beautifully smooth texture, have received the name of Porcelain Crabs. In their form they resemble the true Crabs, and like these their anterior feet are converted into powerful nippers: but their tails, although bent under their body, are furnished with a small fan-like fin. The outer antennæ are very long, and the fifth pair of feet are rudimentary. Like the preceding family they generally live buried in the sand.

In the remaining families of the *Anomura*, the tail is destitute of terminal appendages, and the form gradually approaches that of the true Crabs. In the *Raninidae*, the four hinder pairs of legs are nearly equal in size, and flattened so as to form natatory organs.

In the *Homolidae*, the three middle pairs are long and cylindrical, whilst the fifth are much shorter, furnished with a prehensile claw, and placed quite at the back of the animal, or concealed under the carapace; the inner antennæ also are of considerable length; and in the *Dromiidae*, which make the nearest approach to the *Brachyura* the fifth and sometimes the fourth and fifth pairs of legs, are altered in form as in the preceding family; but the inner antennæ are short, and capable of being concealed in small pits situated at the front of the head.

SUB-ORDER III.—BRACHYURA.

General Characters.—In the *Brachyura*, of which the common edible Crabs may serve as examples, the abdomen is always converted into a short, jointed tail, quite destitute of terminal appendages, and bent round so as to fold closely under the breast (Fig. 134). The cephalothorax is usually of a more or less rounded form,

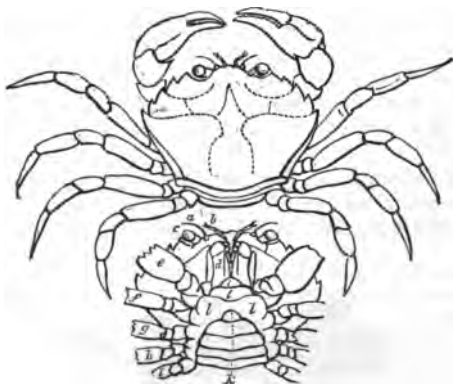


Fig. 134.—*Carcinus Mænas* (Common small edible Crab), upper side, and under side of the body with the limbs cut short; *a*, lateral antenna; *b*, intermediate antenna; *c*, eye; *d*, outer foot-jaw; *e*, *f*, *g*, *h*, *i*, base of the five pairs of legs; *k*, tail; *l*, sternum.

generally broader than long, and often produced in front into a point. The upper surface is entirely covered by a single plate (the carapace). The eyes and the inner antennæ, the latter of which are very short, can be entirely concealed within small cavities of the forehead. The outer antennæ are never of any great length, and the anterior feet are always converted into nippers. The four other pairs of legs are generally terminated only by single claws. They are sometimes flattened to assist the animals in swimming; but, as a general rule, the feet are formed

exclusively for running. This is performed, not forwards, as in most other animals, but with a curious sidelong gait; and the aspect of a Crab, when making his escape from danger, with his claws extended, and every limb in the most rapid though awkward motion, is often very droll.

The tail of the female Crab is always much broader than that of the male, and bears four pairs of filiform appendages on the side which is applied to the breast. To these the eggs are attached, so as to be protected by the horny plates of the tail, until the young animals are developed. These, on first coming out of the egg, are active little fellows, with long tails, which, after their first moulting, acquire a singular spine on the middle of the back, whilst a similar spine is developed, at the front of the head (Fig. 99, p. 296). These were described, when first discovered, under the generic name of *Zoea*. At a later period the eyes become pedunculated, the legs acquire somewhat of their mature form, the nipping claws of the anterior pair are developed, and the spines disappear. In this form the young animals have received the name of *Megalops*. It is to be observed, however, and this constitutes one of the most singular facts in the history of these animals, that this metamorphosis is by no means universal amongst the *Brachyura*,—the young of some species, like those of the *Macrura*, nearly resembling their parents from the moment of their leaving the egg; whilst those of others, nearly allied to these, undergo a regular series of changes before arriving at their mature form.

Divisions.—Professor Milne Edwards divides the *Brachyura* into four families. The first family, the *Oxytomata*, have the carapace orbicular, and arched in front; and the openings for the passage of water to and from the branchial cavities are placed

close together in front of the mouth. The anterior claws are often of very large size, and curiously compressed; so that they can be applied to the sides of the cephalothorax so closely as to be invisible from above. The other legs vary greatly in their development, being sometimes long and stout, sometimes short and weak; sometimes formed exclusively for walking, and sometimes more or less flattened to form natatory organs. In the genus *Dorippe*, the fourth and fifth pairs of legs are reduced in size, placed quite at the back of the animal, and terminated by curious prehensile hooks.

In the second, the *Oxyrhyncha*, *Maiada*, or Sea-Spiders, the carapace is more or less



Fig. 135.—Spider Crab (*Maia*).

narrowed in front, forming a projecting beak or rostrum (Fig. 135); the legs are long and hairy; the back usually covered with spines and hairs, whence the name of Sea-

Spiders, or Spider-Crabs, by which these animals are commonly known. These Crabs generally live in deep water, and rarely approach the shore. Of the third family, the *Cyclometopa*, or *Canceridae*, the common edible Crab (*Cancer Pagurus*, Fig. 136), may serve as an example. In this family the shell is regularly rounded in front, and narrowed behind; the legs are of moderate length, the claws large, and often unequal in size. The common Crab is too well known to need description. It inhabits deep water, and is captured in large quantities, by sinking baskets, pots, or nets, baited with carrion, in places which it is



Fig. 136.—*Cancer Pagurus*.

known to frequent. The small edible Crab (*Carcinus Menas*, Fig. 134) is also well

known. It is to be met with, in profusion, on all our shores. It is less esteemed than the larger species, and is principally consumed by the poorer classes. Many other species are eaten in different parts of the world. Some, of which the Long-stalked Crab (*Podophthalmus*, Fig. 96) is an example, have the posterior pair of feet converted into paddles.

In the *Catomatopa*, or *Ocypodidae*, forming the fourth family, the carapace is usually quadrilateral, sometimes oval, with the front generally transverse and knotted. The abdomen of the male does not occupy the whole space between the hind legs. This group is represented in the British seas by the little Pea Crabs (*Pinnotheres*), which shelter themselves within the shells of many of the bivalve *Mollusca*, especially the common Mussel.

The ancients were acquainted with one species of *Pinnotheres*, which inhabits the shell of the *Pinna*, a common Mediterranean Mollusk. They believed that the connexion between the Crab and the Mollusk was one of mutual advantage; and that the former, in return for the protection afforded to him by the shell of his host, not only gave him timely notice of any approaching danger, but also procured him his food.

The most remarkable members of this family are the Land Crabs of tropical climates, which are furnished with a peculiar apparatus of leaflets, for retaining moisture in the interior of their branchial cavities. Many of these animals live upon the sides of mountains, at a great distance from the sea, which, however, they regularly visit once a year, for the purpose of depositing their eggs. They generally select moist localities for their terrestrial residence.



Fig. 137.—Land Crab (*Gecarcinus*).

Here they excavate considerable burrows, in which they conceal themselves during the day, roaming about at night in search of food. But some, such as the *Gecarcini* (Fig. 137), are said to inhabit dry woods. The *Cardisoma carnifex*, which usually inhabits the Mangrove swamps of the West Indian Islands, lives principally upon the fruit of a species of *Annona*, which grows in those places. But nothing comes amiss to it. Those individuals whose residence is in the neighbourhood of the cemeteries are said to burrow down to get at the dead bodies; and Dr. Duchassaing tells us; that the West Indian burial grounds are pierced in every direction by the burrows of these animals. Nevertheless the *Cardisoma* is regarded as a luxurious article of food by the West Indians; who, however, take care only to eat those which live in the Mangrove swamps, as far as possible from the cemeteries. They are caught in box rat-traps, baited with a piece of their favourite fruit; and after their capture they are usually kept some time, and fattened with broken victuals. Another group of Land Crabs, the *Gelasini*, are distinguished by the large size of one of their claws, which they hold up in a menacing attitude as they retreat from any object that has inspired them with alarm. From the beckoning action of this claw, the *Gelasini* have received the name of *Calling-Crabs*. They make great use of it also in forming their burrows, bringing up small pinches of sand or earth every now and then, and scattering these waste materials to a considerable distance round their hole, so as to avoid the presence of an

unightly heap at the entrance to its domicile. The *Thelphusa* (Fig. 4, p. 198) are also Land Crabs, although some of the species inhabit fresh water.

CLASS VI.—ARACHNIDA.

General Characters.—The animals forming the class *Arachnida*, which includes the Spiders and their allies, are amongst those which are viewed with disgust and aversion by the generality of mankind. Confounded, in the popular mind, with the Reptiles, they of course come in for their share of the bad reputation of those creatures, and some of them, no doubt, not without reason; but on a closer examination we find that, however unattractive they may be in appearance, they present much that is interesting both in their structure and habits.

They are distinguished from the other *Arthropoda* by their aërial respiration, their possession of four pairs of legs attached to the anterior division of the body, and the total absence of antennæ. The body is usually covered with a softish skin, which, however, sometimes attains a horny consistency. In the lower forms the division of the body into separate regions is quite unrecognizable, and the whole forms a roundish or oval mass, which does not even present traces of segmentation. In the higher groups the body is composed of two principal divisions, of which the anterior, as in the *Crustacea*, consists of the thoracic segments, amalgamated with those of the head, and forming together a mass called the cephalothorax. In the highest forms the division of the thorax into separate segments becomes apparent; but the anterior segment is still amalgamated with the head. The structure of the abdomen varies greatly. In some cases it forms a soft round mass without any traces of segmentation; whilst in others, as the Scorpions, it is produced into a long flexible jointed tail.

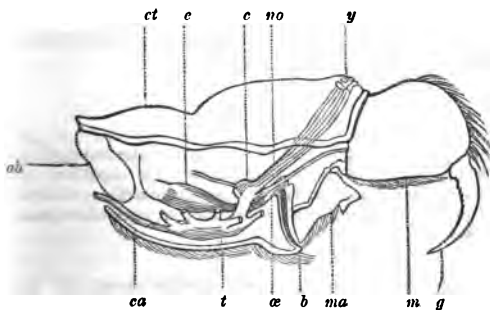


Fig. 138.

Fig. 138.—Section of the Cephalothorax of a *Mygale*, showing the arrangement of the nervous system. *ct*, cephalothorax; *m*, mandible; *g*, moveable hook which terminates it; *b*, mouth; *æ*, œsophagus; *e*, stomodæum; *ab*, origin of abdomen; *c*, cephalic ganglion; *t*, ganglionic mass of the thorax; *ca*, cords which unite it to the abdominal ganglia; *no*, optic nerve; *y*, eyes.

Fig. 139.—Buccal apparatus of a Spider. *s*, sternum; *l*, labrum; *ma*, maxillæ; *p*, maxillary palpi; *m*, mandibles; *g*, hook terminating the mandibles.

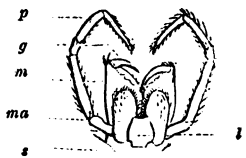


Fig. 139.

In most of the *Arachnida* the cephalothorax is armed in front with a pair of powerful jaws, terminated by a distinct claw-like joint (Fig. 139); these are usually perforated, and convey a poison into the wounds inflicted by them, which, although it rarely produces disagreeable effects upon the human subject, appears to be very speedily

fatal to the small animals upon which the Spiders prey. These jaws are considered to be the representatives of the antennæ of the other *Arthropoda*. Below them is the opening of the mouth, which is furnished with jaws of a different construction, called *maxilla* (Fig. 139), bearing on their outer surface long jointed organs, called *palpi*, which often attain an enormous development, and are furnished with a pair of pincers at their extremity. In many of the lower forms the mouth is converted into a sucking proboscis.

The legs are usually formed of the same parts as those of Insects; a rounded hip-joint (*coxa*) attaches the limb to the sternum; the thigh is united with this by a small moveable joint called the *trochanter*; the joint following this is the shin (*tibia*), at the extremity of which is the foot (*tarsus*), usually composed of two joints. The nervous system in the higher groups is well developed, consisting of a large nervous mass situated in the lower part of the cephalothorax (Figs. 138 and 140), communicating with a brain, or supra-oesophageal ganglion by a band of nervous matter which embraces the oesophagus; and of one or more ganglia placed in the abdomen and united with the thoracic mass by a pair of filaments. In the Spiders there is usually only a single

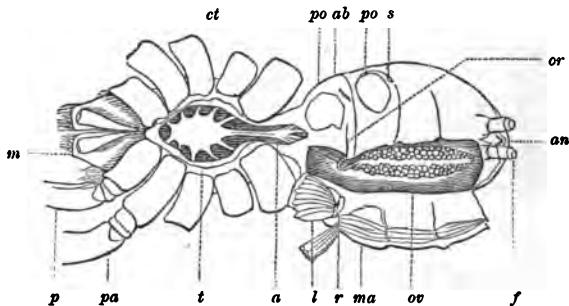


Fig. 140.—Anatomy of *Mygale*. *ct*, cephalothorax opened below, and giving attachment to the limbs, whose first joints are exhibited; *pa*, legs of the first pair; *p*, palpi; *m*, mandibles; *ab*, abdomen; *t*, thoracic nervous mass; *a*, abdominal ganglia; *po*, respiratory sacs; *s*, stigmata; *l*, leaf-like folds in the interior of one of these laid open; *or*, ovaria; *or*, orifice of oviducts; *ma*, muscles of the abdomen; *an*, anus; *f*, spinnerets.

ventral ganglion; but the Scorpions have one of these nervous knots in each segment of the abdomen. The eyes are situated on the upper surface of the front of the cephalothorax (Fig. 138); they vary in number from two to eight, and are of the kind called ocelli, or simple eyes. Other organs of sense have not been recognized.

Respiration is effected by means of air-tubes (*tracheæ*), or by peculiar modifications of those organs which, in their most perfect form, have received the name of pulmonary sacs. The blood is set in motion by the contraction of a dorsal vessel (Fig. 141), which propels the nutritive fluid from behind forwards, and gives off numerous minute arteries; no veins have been discovered. The intestine is sometimes a simple canal, running in a tolerably straight direction from one extremity of the body to the other; but in most cases the oesophagus leads into a sac-like stomach, furnished with nume-

rous blind processes, which are sometimes confined to the cavity of the body, but frequently send branches into the legs.

The *Arachnida* are all unisexual, and all lay eggs, with the exception of the Scorpions and a few Mites, in which the ova are retained within the oviducts until they are hatched, so that the animals produce living young. In the majority of the *Arachnida*, the young, on escaping from the egg, present the same general form that they are to retain through life; but amongst the lower forms, such as the Mites, the young are often comparatively imperfect, sometimes possessing fewer legs than the perfect animal, and sometimes having the same number of those organs, but in a less developed condition.

Divisions.—The *Arachnida* may be divided into two large groups or subclasses, in accordance with differences in the structure of their respiratory apparatus. In one of these sections the animals (when respiratory organs have been detected) breathe by means of air-tubes, or tracheæ, and the eyes are never more than four in number; these form the subclass *Trachearia*. In the second section the respiratory organs take the form of pulmonary sacs, and the animals are hence called Pulmonaria; they possess six or eight eyes. The first of these subclasses includes three orders—the *Podosomalata*, which appear to possess no special breathing apparatus, and which are distinguished from all other *Arachnida* by their marine habitation; the *Acarina*, or *Monomerosomata*, in which the body is usually composed entirely of a single mass; and the *Adelarthrosomata*, which have the abdomen more or less distinctly annulated.

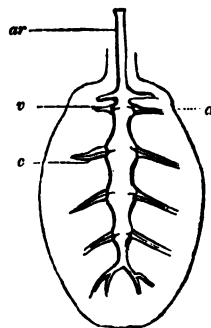


Fig. 141.—Heart of a Spider. a, border of the abdomen; c, heart; ar, large artery, proceeding from its anterior extremity; v, pulmonary vessels.

SUBCLASS I. — TRACHEARIA.

ORDER I.—PODOSOMATA.

This order is composed of a few singular spider-like creatures, which have been shifted about by different authors, backwards and forwards, between the *Crustacea* and the *Arachnida*. They are all marine; some of them, like the *Nymphon* (Fig. 142), being found amongst stones and sea-weeds on the beach, or amongst rocks and corals in deep water; whilst others, such as the *Pycnogonum* (Fig. 143), attach themselves parasitically to Fishes and other marine animals; the species figured lives upon whales.

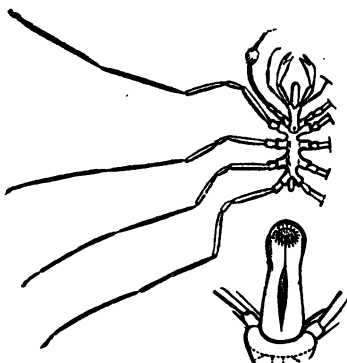


Fig. 142.—Nymphon Grossipes, and under side of its beak.

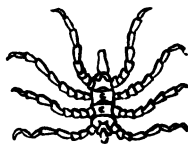


Fig. 143.—Pycnogonum Balaenarum.

The body is composed of four segments, amalgamated into a regular cephalothorax, and

each segment bears a pair of long jointed legs. In front of this mass is a short rostrum, which is sometimes accompanied by a pair of palpiiform jaws; and between these and the first pair of feet, the females of some species possess a pair of false feet (Fig. 142), to which the eggs are attached. The stomach gives off long processes, which sometimes run almost to the extremity of the legs; but no circulatory or respiratory organs have yet been recognized. The nervous system is very imperfectly developed. The young, on first leaving the egg, possess only four short legs, furnished with long filaments; their metamorphosis has not been observed.

These animals form two families: the *Pycnogonidae*, which are parasitic in their habits, and have the palpi obsolete; and the *Nymphonidae*, which crawl about slowly amongst the stones and weeds of their aquatic home, and are furnished with distinct palpi.

ORDER II.—ACARINA, OR MONOMEROSOMATA.

General Characters.—Nearly all the animals that we include in this order—of which the common Mites are the best known examples—are recognisable at the first glance by the form of the body, which usually constitutes a roundish or oval mass, without any trace of segmentation. They are mostly parasitic animals, furnished with a proboscis containing a pair of sharp spines, which serve for wounding their prey, and bearing a palpus on each side. The intestine is always furnished with lateral processes, which are often recognisable externally by their effect upon the colour of the animal. The proboscis is jointed and retractile. Sometimes it is furnished with a swollen base, which has been taken for a head. The eyes, which are often wanting in the parasitic forms, are two in number when present, and are placed on each side of the anterior portion of the body. The respiratory organs consist of tracheæ or air tubes, similar to those of insects; these arise from a pair of lateral openings, and ramify through the body. Their structure will be described when we come to treat of the insects, in which the tracheæ are presented in their most characteristic form.

The *Acarina* are generally oviparous animals; but a few bear living young. The young generally possess only three pairs of feet; the fourth pair not making their appearance until after the first moult.

Divisions.—We must refer very briefly to the numerous families into which this order is divided. The three first of these groups, like the earlier families of the *Crustacea*, are composed of animals in which the characters even of the class are almost



Fig. 144.—*Linguatula Tenuoides*.

entirely lost by degradation; and although their general structure appears to indicate this as their proper position, they have been placed in very different situations by some zoologists. The first of these, the *Linguatulidae*, containing the *Linguatula* (Fig. 144), curious worm-like animals, found in the frontal sinuses and lungs of various *Mammalia*, and in the lungs of some Reptiles, has generally been placed amongst the intestinal worms; but recent investigations have shown that the young of these creatures greatly resemble the *Acari* in the form of their body, and that they are furnished, whilst still in the egg, with four short, jointed legs. The creature resembles a jointed worm, with no traces of external organs, except two pairs of hooks

placed close to the mouth, which serve to maintain the animal in its position. The second family, the *Simoneida*, also includes parasitic animals; but these select a more singular habitation than the *Linguatula*. They are minute, soft creatures, furnished with four pairs of legs, which frequently take up their abode in the follicles of the human skin; they are vulgarly denominated "maggots in the skin."

In the structure of the mouth these creatures agree with the Mites; their bodies, when young, are much elongated, but gradually shorten as they approach maturity. They never exhibit any appearance of segmentation. The species found on man, *Simonea folliculorum*, usually confines its attacks to the face, and appears to be particularly partial to the nose.

The third of these doubtful Acarine families, is that of the *Macrobiotida*—microscopic animals which have usually been associated with the *Infusoria*, and especially with the *Rotifera*. They are known as Sloth or Bear-animalcules, and they are to be found in moss or in fresh water. Their bodies are usually of an elongated oval form, furnished with four pairs of legs, of which the hinder are placed at the extremity of the body. The mouth is furnished with a short rostrum, armed with a pair of sharp, moveable spines. The feet generally bear four claws. No trace of a circulatory or respiratory apparatus has been found in these creatures; and in one genus only do any indications of annulation present themselves.

The most singular fact, connected with these curious little creatures, is their power, although inhabitants of water or moist situations, of retaining their vitality for an indefinite period of perfect drought and returning to life the moment they are again moistened. The most fruitful locality in which to search for them is



Fig. 145.—*Macrobiotus* Hufelandi, seen from the back. *a*, armature of mouth; *b*, eye; *c*, stomach; *d*, ovary; *e*, hind feet.

one in which we should scarcely suspect the existence of anything animated—namely, amongst the sandy dust that collects in the gutters on the roofs of houses. Here, however, they may generally be met with, not unfrequently associated with other animalcules, in which, as we have already seen, the same resuscitation also takes place.

Of the family of *True Mites* (*Acarida*) some are active in their habits, like the common Cheese Mite (Fig. 146); others are parasitic upon or beneath the skins of men



Fig. 146.

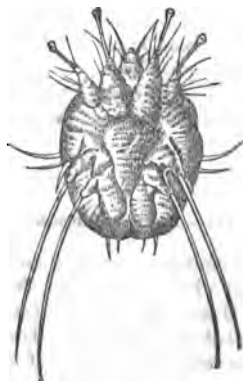


Fig. 147.

Fig. 146.—*Acarus domesticus*, or Cheese-Mite, magnified.
Fig. 147.—*Sarcoptes Scabiei*, or *Acarus* of the Itch.

and other animals. Of the latter, one species is well-known by its effects; this is the *Sarcoptes Scabiei* (Fig. 147), which produces the disgusting complaint so common amongst dirty people, known as the itch.

The *Ixodidae*, forming another family, are furnished with a powerful rostrum, armed with recurved spines (Fig. 148), with which they pierce the skin of the unfortunate animals upon whose blood they live. So firmly does this anchor-like organ retain its hold, that if the parasite be pulled away it usually carries a portion of the skin of its victim with it. These creatures live upon a great variety of animals. The dog is very liable to their attacks, and many species attach themselves exclusively to serpents and other reptiles. The animal known as the Harvest Bug, which is often so troublesome in summer and autumn, also belongs to this group. The *Gamasidae*, which are furnished with a sucking apparatus very similar to that of the *Ixodidae*, usually attach themselves to the bodies of beetles; and the common Dung-beetles (*Geotrupes*) may often be found with the lower surface nearly covered with them.



Fig. 148.—*Ixodes Plumbeus*, and its Rostrum.

In the preceding families—most of which are parasitic in their habits—the eyes are usually wanting. The remainder, which generally lead a more active life, are always furnished with these organs. One family, the *Hydrachnidae*, or Water-mites, inhabit the water, where they swim about with considerable rapidity by means of their fringed legs (Fig. 149). In their young state, they attach themselves parasitically to aquatic insects; they then possess only six legs, and pass through a quiescent or pupa state before acquiring the fourth pair. The *Oribatida*—which, unlike the other *Acarina*, live upon vegetable matter, principally the leaves of mosses—are covered with a hard and very brittle skin, and have the mouth adapted for biting. The *Bdellida*, which live amongst damp moss, have the body divided apparently into two parts by a constriction, and the rostrum and palpi very long; whilst the *Trombididae*, of which the little Scarlet Mite so often seen in gardens is an example, have the palpi converted into little raptorial organs.



Fig. 149.—*a*, *Hydrachna Globulus*; *b*, magnified; *c*, young larva; *d*, pupa.

ORDER III.—ADELARTHROSOMATA.

General Characters.—The animals composing this order have the abdomen united to the cephalothorax by its whole breadth, and the body sometimes presents a regular oval outline, as in the Mites; but the abdomen, on close examination, is always found to be more or less distinctly annulated. The mouth is armed with jaws like those of the Spiders; and the palpi are generally of great length, and converted into nipping claws (*chelicerae*), like those of the Scorpion, to which some of these creatures bear no very distant resemblance. Like the Mites, they respire by means of tracheae, which open by two or four openings on the lower surface of the body.

Divisions.—These animals form three families. In the first, the *Phalangida*, of which the Harvest-men, or Harvest Spiders (Fig. 150) of our gardens and fields are well-known examples, the division of the abdomen into segments is often indistinct; the antennal jaws are large and furnished with a didactyle claw; the palpi are of moderate length, and the legs in general immoderately long. Propped upon these stilt-like limbs, the *Phalangia* stalk about amongst plants in search of insect prey, and they seem to be very voracious animals. Some exotic forms belonging to this family are remarkable for the extraordinary shape of their abdomens, which project into angles and spines of all imaginable forms.

Fig. 150.—Harvest Spider (*Phalangium*).

The *Cheliforida*, forming the second family, are at once distinguishable by the form of their palpi, which are very long, and terminated by strong nippers, like those of the Scorpion. These animals, in fact, resemble little Scorpions that have lost their tails (Fig. 151). Like the preceding, they are predaceous in their habits, and often get into houses in search of food. They are frequently found amongst old books, which they visit, no doubt, in pursuit of the minute insects sometimes to be met with in such situations. They occasionally attack the common House-fly, and run quickly in every direction, backwards, forwards, and sideways, like little crabs. Their appearance, with their little claws extended, is very curious.

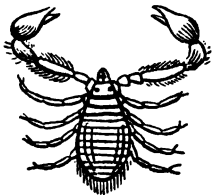


Fig. 151.—Chelifera.

The last family, the *Solpugida*, includes several spider-like animals, some of which enjoy a most unenviable reputation. The antennal jaws and palpi are of very large size; the latter being longer than the three anterior pairs of legs. They live principally in the sandy deserts of the old world, where the common species (*Galeodes araneoides*, Fig. 152), which attains the length of about two inches, is said to be a great torment to the camels.

Fig. 152.—*Galeodes*.

They run with great swiftness, and are very voracious, sometimes even attacking small birds and lizards. When threatened, they retreat with their head and formidable nippers raised in an attitude of defiance; and their bite is said, by the natives of the regions they inhabit, to be extremely venomous.

SUB-CLASS II.—PULMONARIA.

The pulmonary sacs, the presence of which is the leading characteristic of these animals, are to be regarded merely as modifications of the tracheary structure presented by the other *Arachnida*. Like the tracheae, they open by stigmata, or small apertures in the lower surface of the animal; but these, instead of leading into a tuft of little tubes radiating amongst the organs of the body, admit the air into a small closed sac, con-

taining a packet of minute plates, laid side by side like the leaves of a book (Fig. 140). These animals possess six or more eyes, placed on the anterior portion of the cephalothorax (Fig. 153). They are always ocelli or simple eyes, each furnished with its own separate nervous filament.



Fig. 153.—Eyes of Spider.

The *Pulmonaria* form two orders—the *Polymerosmata* or *Pedipalpi*, in which the abdomen is distinctly annulated and attached to the cephalothorax by its whole breadth; and the *Dimerosmata*, or true Spiders, in which that region of the body presents no signs of segmentation, and is connected with the preceding segment by a narrow peduncle.

ORDER IV.—PEDIPALPI OR POLYMEROSMATA.

General Characters.—The principal distinctions existing between these animals and the true Spiders, which constitute the following order, are the great development of the palpi, which always form large arm-like prehensile organs, often terminated by a pair of nippers, and the distinctly annulated structure of the abdomen. The skin is always hard and horny; and the abdomen is attached to the back of the cephalothorax by its entire breadth.

Divisions.—This order includes only two families, and the species in these are not particularly numerous; but few of the *Arachnida* are more renowned than these,

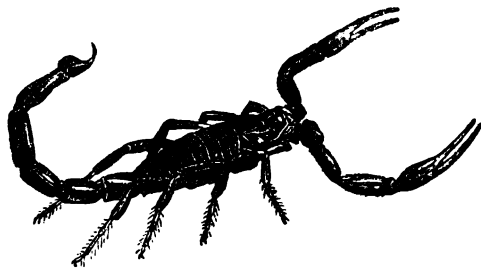


Fig. 154.—Scorpion.

from the universal dread inspired by the venomous powers of their best known representatives, the Scorpions. These form the family *Scorpionidae*, characterized by their elongated tail-like abdomen (Fig. 154), armed at its extremity with a sort of hooked claw, which, when the creatures are in motion, is always carried over the back in a most threatening attitude. This

claw-like organ is the sting, of the formidable nature of which such extraordinary accounts are given by the natives of those tropical regions to which, fortunately for Europeans, the largest and most dangerous species are confined. The poison glands are situated close to the base of this organ, and their ducts run to its point, so that when the creature strikes with its weapon, a small portion of the venom is instilled into the wound. Whether this venom is ever fatal to human life, appears still to be a matter of dispute; but the effects of the Scorpion's sting are, doubtless, very disagreeable; it often produces great and painful swelling of the part wounded, accompanied in many cases with vomiting and other symptoms. Moreover, the venom of some species is said to be rapidly fatal to man; and an African genus has received its name (*Androctonus*, manslayer) from its evil reputation in this respect. As to the effects of this poison upon smaller animals there can be no doubt; as the Scorpions destroy their prey, which consists principally of insects, by holding them in their claws, and stinging them to death. Some of the larger species also capture small lizards and other animals, which they destroy in the same manner.

The Scorpions have four pairs of stigmata and pulmonary sacs placed upon the first

four segments of the abdomen. Behind the last pair of legs, a pair of curious comb-like organs is placed, the office of which is not known; but the aperture of the generative organs is situated between them. The female Scorpion exhibits the greatest care for her young, carrying them upon her back for some days after they are hatched, and attending to them closely for about a month, after which they are able to take care of themselves. They generally live on the ground under stones and in dark places, coming out at night in search of prey; but they frequently find their way into the interior of houses, where they are sometimes so numerous, that in some places it is said that scarcely an article of furniture can be moved without the greatest danger of being stung by some concealed Scorpion, irritated at this unexpected intrusion on his privacy.

The animals forming the second family, the *Thelyphoridae*, present an appearance in some degree intermediate between the Scorpions and the true Spiders. The abdomen is short and rounded, but distinctly annulated; the cephalothorax forms a single mass; the palpi are very long and stout; but, instead of the pincers of the Scorpion, they are terminated by a moveable claw, capable of being applied to the inside of the preceding joint, and thus forming a prehensile organ. The structure of the anterior pair of feet is very remarkable; they are much thinner than the other three pairs, and the tarsi are formed of a great number of joints; so that the limbs are converted into long flexible organs of touch, which probably fulfil the office of antennae. Many of them are large animals, of a somewhat forbidding appearance, which, like the Scorpions, can run in every direction. They are almost confined to tropical countries, inhabiting principally the hottest parts of Asia and America.

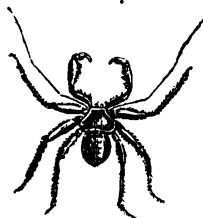


Fig. 155.—*Phrynos reniformis* (reduced).

ORDER V.—DIMEROSOMATA.

General Characters.—The general appearance of the animals forming this order must be familiar to all our readers. The body consists of two distinct portions, of which the anterior, or cephalothorax, is usually of an oval form, and covered with a plate of a somewhat horny consistence; whilst the posterior (the abdomen) generally forms a soft, roundish mass, without any traces of segmentation, and which is attached to the base of the cephalothorax by a narrow peduncle.

On its anterior portion the cephalothorax bears six or eight simple eyes (Figs. 138 and 153), which are usually situated on a slight eminence. Below and in front of these are seen the large mandibles (Figs. 138, 139), which serve the Spiders for the destruction of their prey, below which is the opening of the mouth, furnished with a pair of masticating jaws, or maxillae. From each of these springs a long, jointed palpus (Fig. 139), which in some instances appears to be converted into a supplementary leg. These organs occupy the front of the cephalothorax. Its lower surface bears four pairs of jointed legs, furnished at their extremities with claws, which are often of a very singular, comb-like structure.

The pulmonary sacs, which are contained in the abdomen (Fig. 140), are either two or four in number, opening by stigmata in the lower surface of the abdomen. Besides these respiratory organs the majority exhibit an aperture at the extremity of the abdomen, from which four flat tracheae arise, and ramify through the organs of the body.

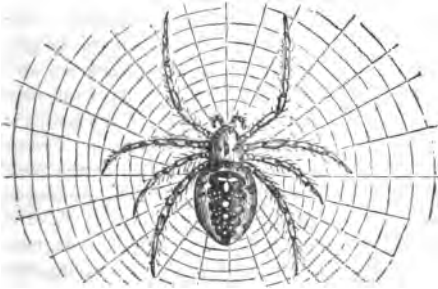
But the most remarkable organs, perceptible on the abdomen of spiders, are the *spinnerets* (Fig. 140 *f*), by means of which these animals spin their curious and often

beautiful webs, which have attracted the attention and excited the admiration of mankind in all ages. These spinnerets are little test-like organs, placed close to the extremity of the abdomen, on its lower surface. They are sometimes four, sometimes six in number; and may usually be recognised by the naked eye. Each of them bears at its apex a multitude of minute tubes, of which as many as a thousand are present in some species; so that the delicate thread, by which these creatures suspend themselves in the air, must frequently be composed of at least four thousand slender filaments. The substance of which the threads are composed is secreted by glandular organs, situated in the abdomen, close to the base of the spinnerets. It is a viscid fluid, which speedily hardens on exposure to the air. The spider usually commences its thread by applying the spinnerets to some fixed object; to this the glutinous secretion attaches itself, when the movements of the creature are sufficient to draw out the materials necessary for the continuation of the thread. The hind feet are always applied to the thread at a short distance from the spinnerets, probably in order to bring the numerous filaments into contact before their hardening has proceeded too far to allow of their adhesion. This power of spinning threads is of the greatest importance to all these animals, as it not only serves many of them for the construction of dwellings, and of nets for the capture of prey, but appears to be constantly employed in securing them from falls whilst in motion, or in descending in a direct line from an elevated position to some object below them. Many of them have the faculty of emitting threads, one end of which floats freely in the air, until it meets with some object to which it adheres. By this means spiders often form natural bridges, by which they can pass over brooks and ditches. Some species avail themselves of the same power to take long flights in the air, where they often attain great altitudes. Those spiders, whose instinct prompts them to employ their spinning powers in regular weaving operations, manifest this in various ways. Some—of which the common garden Spider (*Epeira diadema*, Fig. 156) is an excellent example—construct a beautiful net, composed of stout radiating lines, intersected at tolerably regular intervals by circular filaments. It appears that the latter are beset by an immense number of viscid globules, which doubtless assist greatly in entangling any insect that is so unfortunate as to come in contact with the web of the destroyer. The mode in which the creature forms this elegant structure—its readiness to rush out of its concealment the moment some hapless fly has become entangled in its meshes—the rapidity with which it shrouds its victim in a silken coat—and the care with which it repairs any damage done to its net—are all so exceedingly interesting, that we regret that our space will not permit us to dwell at length upon these points.

The nets of some of the large tropical Spiders are said to be of strength sufficient even to capture small birds. Other species—such as the common House-spider (*Aranea [Tegenaria] domestica*, Fig. 158)—weave a close cloth-like web, usually placed in obscure corners; this is furnished with a sort of funnel-shaped cell, within which the Spider lies in wait for his prey. Others again employ their silk merely to line the holes and crevices which form their ordinary places of abode; and some of these exhibit great ingenuity in the construction of their nests. Another purpose, to which this secretion is applied by all Spiders, is the formation of little silky cases, or cocoons, for the reception of the eggs, which a few species carry about with them. Attempts have been made to employ this silk, which differs considerably in its texture from that of which the nets are constructed, for industrial purposes; but hitherto with very little success.

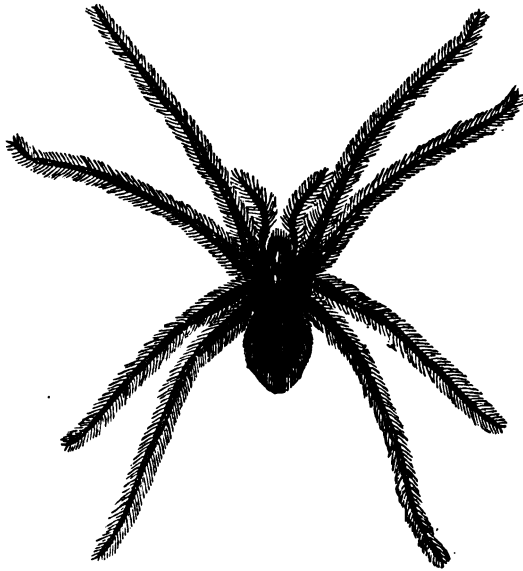
The Spiders are all predaceous animals, and generally of an exceedingly fierce and

sanguinary disposition. They prey with avidity upon insects and other articulated animals of smaller size than themselves; but, unless in self-defence, they do not appear to turn their weapons against the higher animals. Nevertheless, the gigantic species of *Mygale*, which inhabit tropical countries, have received the name of *Bird-spiders*, from a belief that they frequently attack and devour small birds; and Madame Merian, in her book on the Insects of Surinam, has given us a most striking representation

Fig. 156.—*Epeira diadema*.Fig. 157.—*Theridion Malmignatta*.

of a *Mygale* in the act of devouring a small bird, which he has, to use the lady's own expression, "torn from its nest." It is to be feared, however, that in this instance, as in some others, that enthusiastic naturalist was misled by Indian tales; for, from all that we know of the Spiders of the genus *Mygale*, they are strictly terrestrial in their habits, and generally seek their food upon the surface of the ground.

Divisions.—We divide the Spiders into three families, distinguished at once by differences in their structure and habits. Those of the first family, the *Araneidæ*, have the eyes in two rows, one behind the other, the terminal claw of the mandibles directed inwards, and the palpi, although often long, never converted into foot-like organs. They

Fig. 158.—*Aranea (Tegenaria) domestica*.

usually possess six spinnerets and only a single pair of pulmonary sacs. All these Spiders spin themselves a dwelling-place, which is also generally connected with a net for the capture of prey. Perhaps the best known of these is the *Epeira diadema* (Fig. 156), whose threads often force themselves upon our attention in a very disagreeable manner.

This species forms one of the most beautiful of what are called geometrical webs; many of the others form a somewhat similar structure, although without displaying the same wonderful regularity. Of these the Malmignatte (*Theridion Malmignatta*, Fig. 157), a Spider much dreaded in the south of Europe, is an example. Our common House Spider (*Aranea domestica*, Fig. 158) is another well-known species, offending the eyes of the housewife as it constantly does by weaving its dusky web



Fig. 159.—Diving Spider (*Argyroneta aquatica*).

in all dark corners. One of the most remarkable members of this family is the *Argyroneta aquatica*, or Diving Spider (Fig. 159), which weaves itself a curious little bell-shaped dwelling at the bottom of the water, to which it retires to devour its prey. As, notwithstanding its aquatic habits, this animal, like the rest of its order, is fitted only for aerial respiration, it takes care to fill its miniature dome

with air, which it carries down with it from the surface amongst the hairs with which its body is thickly clothed; a process very closely resembling that by which the earliest diving-bells were supplied with air.

The second family, the *Lycoside*, agrees in the structure of its jaws and palpi, and in the number of its spinnerets, with the *Araneide*, but the eyes are arranged in three rows. Unlike the *Araneide*, the animals of this family never construct regular webs for the capture of prey; their utmost exertion of instinct, in this direction, consisting in laying a few threads in the neighbourhood of their dwelling-place. They generally live under stones, in holes in the earth, or in old walls, sometimes lining their habitations with a silken tapestry; and some, which live upon trees, weave themselves a silken nest amongst the leaves or on the branches. They all take their prey by force; some of them running it down by swiftness of foot, whilst others spring suddenly upon their unwary victim. Perhaps the most celebrated of these Spiders is the Tarantula (*Lycosa tarantula*) of southern Europe, whose bite is supposed by the natives of Italy to cause death, unless the patient be relieved by music and violent dancing. Some of these Spiders can run in any direction. A common example is the *Salticus scenicus*, a small species banded with black and white, which may frequently be met with on garden walls. Most of the European species are small; but in hot climates they attain a size scarcely inferior to those giants of the order which form the third family, the *Mygalide*. In these (Fig. 90) the palpi are of great length, terminated by a claw. The last joint also has a regular sole, like that of the feet. The mandibles are of very large size, and their terminal claw is directed downwards (Fig. 138); the pulmonary sacs are four in number (Fig. 140); and the abdomen bears four spinnerets at the apex. Some of these Spiders attain such a large size that their extended legs occupy a circle of six or seven inches in diameter; and it is to these that the practice of bird-catching already alluded to has been ascribed. Species occur on the shores of the Mediterranean; but

they are, for the most part, confined to tropical countries. They resemble the *Lycosida* in their habits, generally living on the ground, in holes, or under stones. Some of them form long twisted burrows for themselves, which they line with silk; and these burrows sometimes extend as much as two feet below the surface of the ground. Some, like the *Cteniza*, close the mouth of their subterranean residence with a most ingeniously-constructed trap-door (Fig. 160), which the inhabitant closes with the utmost pertinacity when any attempt is made to invade the privacy of his domicile. Hence the *Cteniza*—of which several species are found in the south of Europe, and on the shores of the Mediterranean—are generally known as *Trap-door Spiders*. The bite of the large tropical species is said to be very dangerous.



Fig. 160.—Nest of *Cteniza*.

CLASS VII.—MYRIAPODA.

General Characters.—The small class of *Myriapoda*, of which a characteristic example has already been figured (Fig. 3), is in its general characters very closely allied to the insects, although in some respects it appears to approach the *Crustacea*, especially the air-breathing Isopods (*Oniscida*). In the mature state their bodies are generally elongated, and composed of numerous segments, of which only the first and last exhibit any difference in structure from the rest; the articulations of the body being generally exactly similar, and bearing each one or two pairs of jointed legs. The head always bears a pair of jointed antennæ, very similar to those of many insects; and behind the insertion of these, on each side, is a variable number of simple eyes, which, however, are sometimes wanting. The mouth, in its general structure, bears a considerable resemblance to that of the masticating insects, being furnished with jaws, palpi, and an upper and lower lip. Besides these organs, it is armed below with a pair of powerful hooked jaws, which are perforated at their extremity apparently for the emission of a venomous fluid. These are the principal agents in seizing prey.

The succeeding rings, which admit of no division into thorax and abdomen, are each furnished with one or two legs on each side; and close to the insertion of the feet, the stigmata, through which the air passes into the tracheæ, are situated. It is remarkable that, in those species which possess two pair of feet on each ring, each ring also bears a pair of stigmata; whilst in those which have the rings furnished with only a single pair of members the stigmata occur on alternate rings. Hence Latreille, and after him several naturalists, have considered that in the latter case the rings are only half segments, two of which go to form the equivalent of the segment of the double-footed forms. The tracheæ ramify through the organs of the body in exactly the same manner as those of insects.

In their internal anatomy they also exhibit a great resemblance to the insects. Their nervous system consists of a series of ganglia running along the ventral portion of the body, and usually united by a double thread; and the circulation is effected by a long cylindrical dorsal vessel, the structure of which will be explained under the following class. The *Myriapoda* are all unisexual animals. The orifices of the generative apparatus are frequently situated at the anterior portion of the body. In some *Myriapoda* the

young, on first escaping from the egg, possess nearly all the characters of their parents, although the number of segments and limbs is always less, and increases at each change



Fig. 161.—Transformations of *Iulus*. a, b, c, successive stages.

of skin; but some, as the *Iuli*, undergo a sort of metamorphosis (Fig. 161), coming from the egg either quite destitute of feet, or furnished with only three pairs of these organs; and it is not until after several moultings that they attain the same number of legs as their parents. This process appears to occupy a considerable period; and, according to the observations of Pro-

fessor Savi, the *Iuli* occupy two years in their development before the sexual organs make their appearance. This metamorphosis, such as it is, indicates the close alliance of these creatures with the insects; and many authors either include them in the class *Insecta*, or, retaining them in a separate class, associate with them some of the apterous insects which present the closest resemblance with them in their earlier stages.

Divisions.—The *Myriapoda* form two orders—the *Chilopoda* and the *Chilognatha*, which may be readily distinguished by the structure of the antennæ; those of the former never being composed of less than fourteen joints, whilst those of the second order always consist of seven articulations.

ORDER I.—CHILOPODA.

General Characters.—These animals are usually of a flattened form, with the rings protected both above and below by a more or less flattened horny plate, and each ring bears only a single pair of feet, those of the hinder ring being directed backwards in the form of a pair of jointed tails. The antennæ are long and always composed of at least fourteen joints. The structure of the mouth has already been described.

These creatures usually live in the earth or under stones. They run with considerable swiftness in pursuit of their prey, and can even progress backwards by the assistance of their tail-like hind legs, which at other times are dragged helplessly behind them. Their food consists of insects, which they seize with the powerful jaw-like organs attached to the lower lip; and these organs are supposed to inject a poison into the wound they inflict. The bite of some of the large tropical species is said to be exceedingly painful, and even more injurious than that of the Scorpion; although the application of ammonia to the wound speedily relieves the pain of the bite.

Divisions.—The *Chilopoda* are divided into three families—the *Cermatidae*, the *Scolopendridæ*, and the *Geophilidæ*. The *Cermatidae* have the body rather short, with its upper surface covered by eight plates, its ventral surface by fifteen; the legs are very long, and terminated by feet composed of numerous joints. These animals are all exotic, and generally of small size. They conceal themselves amongst the beams and joists of houses.

The *Scolopendridæ*, well known as Centipedes (see Fig. 3), have the body long and divided into an equal number of segments on both surfaces, with the legs rather short, but stout and well adapted for active motion. This family includes all the most powerful and predacious species, those of hot climates certainly attaining a length of twelve inches; and, if we are to believe some travellers, still more gigantic species are to be met with in particularly favourable situations. Thus Ulloa states that specimens

have been seen in Carthagera exceeding three feet in length and five inches in breadth, the bite of which is said to be mortal; but these dimensions are so far above those of any Centipedes that have ever been brought to Europe, that we may be pardoned for receiving them with some little incredulity. Our British species, of which one of the commonest, the *Lithobius forcipatus*, is here represented (Fig. 162), are of comparatively small size, rarely exceeding two inches in length; but even these, when seized, will turn and attempt to fix their jaws into the skin of their captor.

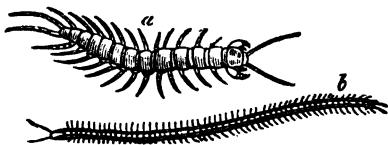


Fig. 162.—a, *Lithobius forcipatus*; b, *Geophilus longicornis*.

The *Geophilidae*, of which a common British species is figured above (Fig. 162), are distinguished by their very elongated and almost thread-like bodies, composed of numerous segments, and bearing a great but variable number of feet. Some species are phosphorescent in the dark. One of these, the *Geophilus electricus*, is not unfrequently met with in the neighbourhood of London.

ORDER II.—CHILOGNATHA.

General Characters.—In the *Chilognatha* the body is generally of a convex form, composed of numerous horny arches, below which an immense multitude of little feet may be seen, whence the name of *Millepedes*, or thousand-legs, by which these animals are commonly known, is derived. Each segment of the body bears two pairs of limbs, with the exception of the hindmost segment, which is destitute of those organs. The antennæ are short, and composed only of seven joints; and the powerful biting jaws of the *Chilopoda* are reduced to a rudimentary condition,—the other organs of the mouth also undergoing considerable modifications. As might be expected from this difference in the structure of the mouth, the food of these animals differs greatly from that of the predaceous members of the preceding order; and the *Chilognatha* are found to feed principally upon vegetable matters, generally when in a state of decay. In accordance with this change of habit, the movements of the creatures, notwithstanding their immense number of legs, are always very slow, and they generally endeavour to escape danger by rolling themselves up into a ball (Fig. 165). They are to be met with constantly in damp moss, and a few live under the bark of trees.

Divisions.—The first of the four families into which the *Chilognatha* are divided contains only a single minute, but very curious, creature, which is often found in great abundance under the bark of old trees. It is about a sixth of an inch in length, composed of eight segments, exclusive of the head and tail. On each side of the body there are nine tufts of little curved hairs; and the extremity of the body is furnished with a tuft of longer straight hairs. This animal is the *Polyxenus lagurus*; it forms the type of the family *Polyxenidae*.



Fig. 163.—*Polydesmus*.

In the second family, the *Polydesmidae*, the form of the body approaches that of the *Scolopendridæ* in the preceding order, being flattened and rather soft; but in other respects the animals resemble the *Iulidæ*. One species, the *Polydesmus complanatus* (Fig. 163), is an inhabitant of Britain.

In the *Iulidæ* (*Iulus*, Fig. 164), the body is elongated, and nearly of a cylindrical



Fig. 164.—*Iulus*.

form, bearing no inconsiderable resemblance to a thick worm, in which the skin has become horny and divided into numerous segments, and

These animals are constantly to be found in sometimes crawling upon trunks of trees. When alarmed they coil themselves up in a spiral form (Fig. 165), with the feet entirely concealed. Their march is very slow, and, from the shortness of their legs, appears more like a gliding motion than a walk.

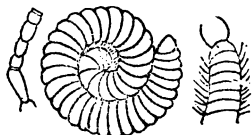


Fig. 165.—*Iulus*, with the body coiled up, and the front of the body unrolled, with the antennæ magnified.

The *Glomeridæ*, forming the fourth family, have a short oval body,



Fig. 166.—*Glomeris marginata*.

closely resembling that of the Woodlouse, which they also resemble in their habit of rolling themselves into a perfect ball when in danger. The body is convex above and concave beneath, where it is furnished with a row of small scales on each side. These animals live under stones.

CLASS VIII.—INSECTA.

General Characters.—We come now to the last and highest class of articulated animals, including the innumerable host of true insects—creatures which, in whatever light we view them, always present many points of the highest interest to our observation. Whether we consider the history of their curious transformations, their extraordinary and often beautiful forms and colours, their wonderful instincts, and the close approach to reason exhibited by some of them, their effects upon our persons and property, or the extraordinary means by which nature avails herself of the instincts of some species to put a check upon the ravages of others—we always meet with much to command our admiring attention; sufficient, in fact, to render the study of insects one of the most attractive pages of the book of Nature. Entomology has this additional recommendation, that it is one of those branches of Zoology that may be pursued in any situation. Insects abound everywhere; and wherever they occur their habits may be observed, and their structure investigated. We regret, therefore, that our limits forbid us from giving more than a very bare outline of their history.

Insects, in their perfect state, are distinguished from the other articulate animals by the possession of six legs and two antennæ, and by the division of the body into three distinct regions, the *head*, *thorax*, and *abdomen* (see Fig. 167), of which the second bears the organs of motion. They respire by tracheæ, are generally furnished with wings, and almost always undergo a series of transformations (the *metamorphosis*) before arriving at their mature and reproductive form.

Like the other *Arthropoda*, the bodies of insects are composed of distinct rings or segments, and these are generally of a horny consistency, united to each other by a

membranous skin which gives flexibility to the whole. In some cases, however, the skin is of a softer texture; but even in these it presents sufficient firmness for the attachment of the muscles, and the tubes composing the limbs are generally of a harder

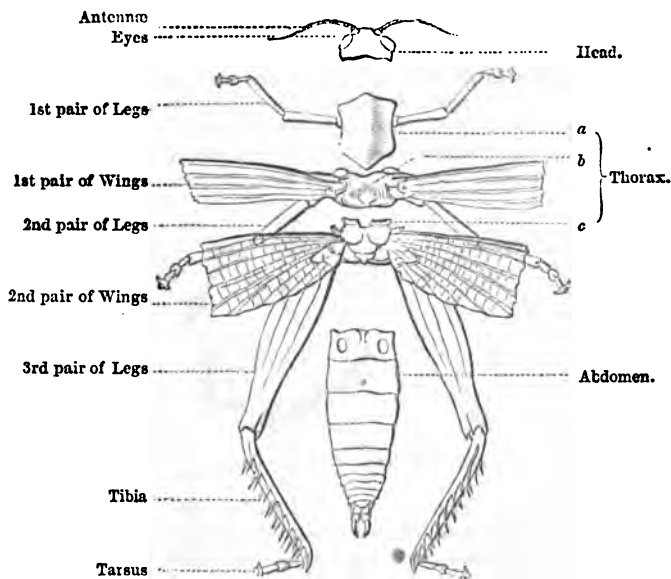


Fig. 167.—Anatomy of the external Skeleton of an Insect.

consistence than the rest of the integument. The number of segments of which the body of an insect is normally composed is thirteen; but some of them are occasionally amalgamated together, or concealed by the others, so as to make it appear that fewer segments are present.

The first segment, or the head, is composed of a single piece, which bears the eyes the antennæ, and the organs of the mouth. The eyes (Fig. 168), which are amongst the most wonderful objects in nature, are almost always of the kind called compound; that is to say, they consist of a multitude of little hexagonal facets, brought close together on each side of the head, each furnished with a cornea, a lens, a coating of pigment, and a nervous filament. The number of these little eyes is sometimes most extraordinary. The eye of the common House-fly has 4,000 of them; that of a

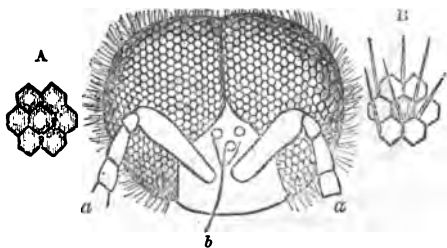


Fig. 168.—Head and Eyes of the Bee.

a a, antennæ; *b*, ocelli; *A*, facets enlarged; *B*, the same with hairs growing between them.

Dragon-fly more than 12,000; of a Butterfly observed by Puget, 17,325; and that of a small species of Beetle (*Mordella*) no less than 25,000. In addition to these compound eyes, many insects also possess two or three *ocelli*, or simple eyes (Fig. 168), placed on the head between the large compound organs; these appear to be very similar in their structure to the individual eyes of which the compound eyes are composed.

The antennæ are usually attached to the front of the head, between the eyes. They are exceedingly variable in their form, and probably vary considerably in function, although their general office appears to be that of organs of touch. In some instances, however, their conformation appears to indicate that they are the organs of some special sense; and the functions of smell and hearing have been attributed to them by different observers. In their most ordinary and simple form, they are more or less filiform

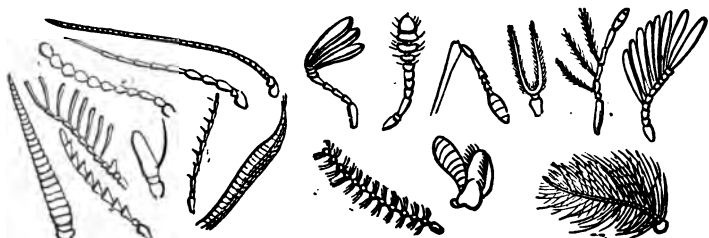


Fig. 169.—Antennæ of various Insects.

organs, composed of a very variable number of joints. Sometimes they are thickened at the base; sometimes at the apex. In some cases the whole or part of the joints are furnished with one or more processes, bristles, or hairs, giving the entire organ a comb-like or feathered appearance; in others the terminal joints are converted into broad plates, folded together like the leaves of a book. These, and several other forms, are represented in the annexed figure (Fig. 169); and we shall meet with a still greater variety as we proceed.

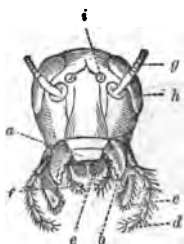


Fig. 170.—Head of Cockroach.

a, labrum; *b*, mandibles; *c*, maxillæ; *d*, maxillary palpi; *e*, tongue; *f*, labial palpi; *g*, antennæ; *h*, compound eyes; *i*, ocelli.

The structure of the mouth in insects exhibits very remarkable modifications; and these are of the utmost importance in the classification of these creatures. In some insects the mouth is formed exclusively for biting; in others, as exclusively for suction; whilst in others again it is fitted for the performance of both these actions; and the form of its constituent parts of course undergoes corresponding changes,—but the same organs really exist in all, modified in appearance, indeed,

so as sometimes to be scarcely recognizable.

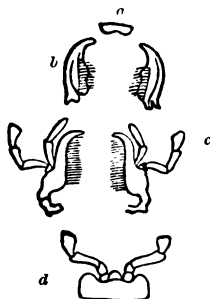


Fig. 171.—Parts of the Mouth of *Carabus*.

a, labrum; *b*, mandibles; *c*, maxillæ; *d*, labium.

In the masticating or biting insects, the mouth (Figs. 170, 171), consists of six separate organs; an upper lip (*labrum*, *a*) attached to the lower part of the front of the head; a pair of horny, curved, biting jaws (*mandibles*, *b*), which are usually armed with teeth; a pair of chewing jaws (*maxillæ*, *c*), generally composed of four pieces, and bearing either one or two pairs of jointed palpi; and a lower lip (*labium*, *d*), which closes the mouth from beneath, and also bears a single pair of palpi (Fig. 170, *e*). On its inner surface it is furnished with a membranous or fleshy organ, to which the name of the tongue has been given.

Amongst the Bees the organs of the mouth take another form, which, whilst it leaves a portion of them fitted for biting, converts the remainder into genuine suctorial

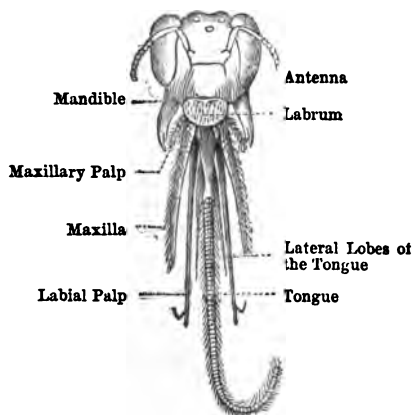


Fig. 172.—Head of *Anthophora*.

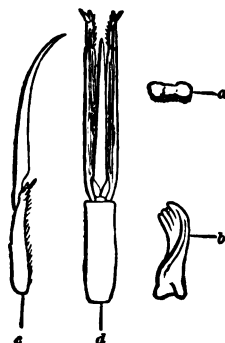


Fig. 173.—Parts of the Mouth separated.

organs (Figs. 172, 173). The parts thus modified are the *maxillæ* and *labium*; the former (Fig. 173, *c*) become greatly elongated, forming a sort of jointed sheath which incloses the elongated tongue (Fig. 173 *d*), constituting a tubular organ through which the fluid nourishment of these creatures can be sucked up. The mandibles and labrum (Fig. 173, *a*, *b*) retain their ordinary form, and the former are constantly employed in the numerous ingenious operations which these industrious creatures perform.

The suctorial mouth presents three principal forms. In the Butterflies and their allies, the suctorial organ consists of a long trunk, which, when at rest, is coiled up in a spiral form beneath the head (Fig. 174). This spiral trunk is composed of the terminal portion of the *maxillæ*, which are more or less elongated, and

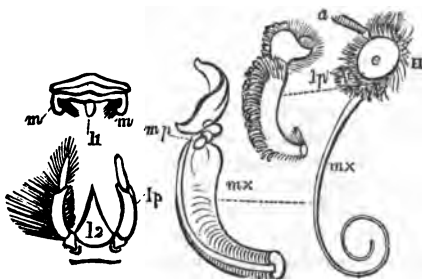


Fig. 174.—Mouth of *Sphinx*.

H, head; *e*, eye; *a*, antennæ; *mx*, maxillæ; *mp*, maxillary palpi; *l*₁, labrum; *l*₂, labium; *lp*, labial palpi; *m*, mandibles.

form two long wrinkled tubes, adhering together along their inner surfaces, and forming a double tubular organ, through which their possessor sucks the juices of flowers. The maxillary palpi are generally of very small size, and only to be detected by dissection; but the labium, although very small, usually bears a pair of very large, hairy palpi, which form the cushions between which the trunk is coiled up when at rest. The mandibles and labrum are also present, although in a very rudimentary condition, and always concealed under the hairs with which the heads of Butterflies are clothed. This structure of the mouth, which is characteristic of the order *Lepidoptera*, will be easily understood by reference to the annexed figures (Fig. 174), in which the organs are represented separate.

In another form of suctorial mouth, which is characteristic of the order *Rhynchota*,

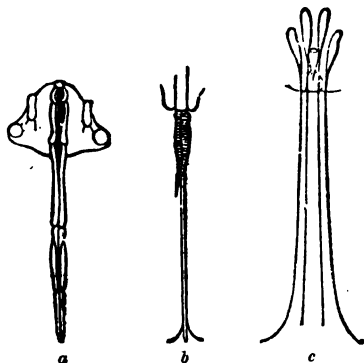


Fig. 175.—Buccal apparatus of an Hemipterous Insect.

including the Bugs and their allies, the mouth is furnished with a jointed rostrum, formed by the coalescence of the labial palpi (Fig. 175 *a*); this is in fact a tube, split down the front, and inclosing four bristle-like organs (Fig. 175 *b c*), which are in reality only the modified mandibles and maxillæ. By means of these bristles, which are sharp at the point, the *Rhynchota* wound the tissues of the animals or plants upon the juices of which they feed. The labrum is generally rather elongated, and serves to close the basal joint of the rostrum. When in the tube, the bristles are pressed very close together, and two of them generally adhere in such a manner as to lead to the appearance of their number being only three (*b*); they are inserted into the head by

broad bases (*c*), to which muscles are attached; and by the action of these they are exerted and retracted.

A third form of suctorial apparatus is presented by the *Diptera*, or two-winged flies, of which the common House Fly is a familiar example. These possess a proboscis (Fig. 176), generally of a fleshy texture; this is composed of the lower lip, is usually bent upwards at a short distance from its base, and terminated by a broad flap (the representative of the labial palpi), which is constantly used as an organ of touch. The upper surface of this proboscis, which forms a tube, is opened below the knee-like bend, to give issue to the true buccal organs, the mandibles, maxillæ, and labrum, which in many of these animals acquire the form of bristles or lancets, and are employed in piercing the skins of other animals and sucking their blood. The maxillæ are generally furnished with a pair of palpi, consisting of from one to five joints; and when, as is

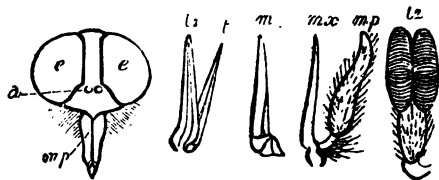


Fig. 176.—Proboscis of a Dipterous Insect (*Tabanus*).
e, eyes; a, ocelli; m, mandible; mx, maxilla; mp, maxillary palpus; l₂, labium.

sometimes the case, the maxillæ, with the other internal organs, are reduced to a rudimentary condition, the maxillary palpi are inserted upon the stalk of the labium at or near the bend. All these types of structure undergo great modifications in different groups of insects; and these differences furnish some of the most important characters for the classification of these animals.

The second division of the body of insects is always composed of three segments, although these are frequently amalgamated together in such a manner as to be almost undistinguishable. The three segments together form the thorax (see Fig. 167); but they are individually distinguished by names indicative of their position in the body, the first being called the *prothorax*, the second the *mesothorax*, and the third the *metathorax*. They vary greatly in their comparative size, and in the amount of their surface visible on the upper part of the body. In some insects all the segments are equally uncovered, whilst in others only the prothorax is visible when the wings are closed; and every intermediate form may be met with.

The thoracic segments always bear the organs of motion, which, in most insects, consist of six legs and four wings. The form of these organs is very various; but their general construction is always similar. The centre of the lower surface of the thorax, or breast, is occupied by a narrow piece called the *sternum*, which frequently projects as a ridge externally, and generally gives off an internal process for the insertion of muscles. On each side of this are the sockets for the legs, of which each segment of the thorax bears a pair. The first joint of the legs, called the *coxa* (or hip), is sometimes immoveably attached to the thorax, sometimes articulated with it by a sort of ball and socket joint. This is followed by a second piece, the *trochanter*, which unites the long thigh (*femur*) to the coxa; this varies greatly in its form, being sometimes ring-shaped, sometimes forming a triangular piece applied against the base of the thigh. The thighs are generally of a rounded form, frequently thickened in the middle or towards the extremity; they are often, especially the hinder pair, of very large size, and armed with spines of greater or less magnitude. The shanks (or *tibia*), which are articulated by a sort of hinge-joint to the extremities of the thighs, are generally about equal to these in length, but thinner, and frequently more or less flattened or angular, and furnished with numerous spines or bristles. At the extremity of the tibia comes the *tarsus*, or foot, which sometimes consists of one, but generally of from three to five joints. The lower surface of these feet is generally flattened and converted into a sort of sole, covered with very close set hair; and the apex of the last joint is almost always furnished with a pair of claws, often beautifully toothed, and in many cases accompanied by a pair of soft membranous organs, called *pulvilli*, which are very distinct in the common fly. These adhere, like sucking-cups, to any object against which they may be applied, and thus enable their possessors to

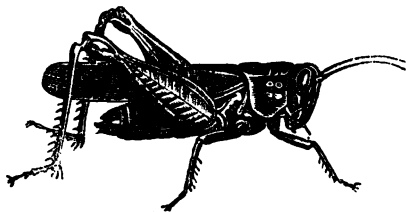


Fig. 177.—Locust.

walk securely even in a reversed position. The legs and their component parts undergo an infinity of modifications in the different groups of insects; always, however, in exact coincidence with the habits of the creatures,—in leaping insects, such as the Grasshopper and the Locust (Fig. 177), the hinder legs are much lengthened and the

thighs very thick, forming powerful jumping organs. In many aquatic species (*Dytiscus* and *Notonecta*) the legs are flattened and fringed with hairs to enable these animals to swim rapidly through the water. In the Mole Cricket (Fig. 178), the fore-



Fig. 178.—Mole Cricket (*Gryllotalpa*).

legs become modified to suit the creature to its burrowing habits; whilst in the *Mantis*, or praying insect (Fig. 179), these limbs are converted into most formidable prehensile organs, with which these insects, reputed so pious by the inhabitants of the countries where they are found, most remorselessly mangle the bodies of their insect prey. Many other modifications of these organs occur; and as these modifications are of great

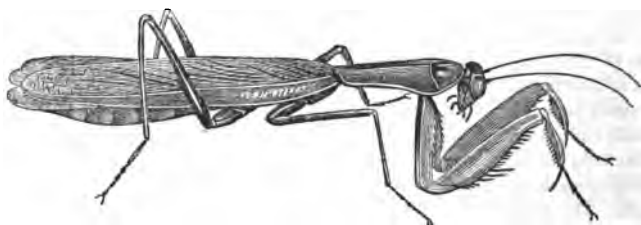


Fig. 179.—*Mantis religiosa*.

importance in the classification of insects, we shall have occasion to refer to them frequently in the sequel.

The wings, of which there are never more than two pairs, are attached to the second and third thoracic segments.

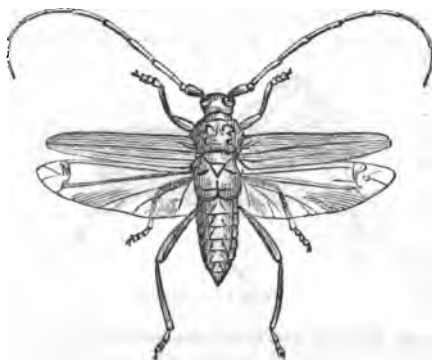


Fig. 180.—*Calliehrhoma Moschata*.

the folding wings of many insects is effected.

They are generally of a membranous texture; but, notwithstanding the delicacy which they often exhibit, each wing is found to consist of a double membrane, between which a variable number of veins, or *nervures*, ramify in different directions. These serve to keep the wings extended; and the characters afforded by their arrangement are often of the greatest importance. These nervures appear to be horny tubes, accompanied by vessels; and it is probably by the injection of fluid into the latter that the extension of

In some insects the four wings are all of a similar texture, and alike available in flight; whilst in others, the anterior pair acquire a firmer consistence, forming a sort of case, within which the large membranous posterior wings can be folded up in repose.

In the Beetles (Fig. 180), the anterior wings generally acquire a horny consistency, and constitute a regular hard shell, covering the back of the abdomen and the wings when the insect is at rest: these are called *elytra*. In the Grasshoppers and Locusts, and some other insects, on the contrary, the anterior wings, although much stronger than the posterior, are still flexible, and possess only a parchment-like texture, in which the nervures may be distinctly recognized; whilst in the Bugs, the basal portion of the elytron, is generally horny, and the apical portion membranous. The wings are generally more or less clothed with minute hairs; these, in the Butterflies and allied insects, usually acquire the form of flattened scales, to which, as is well known, the beautiful colours of those insects are due.

Although the wings of insects are generally four in number, the hinder pair is very frequently absent; and, in fact, one whole order of insects is characterized by the possession of only one pair of wings. In these (Fig. 181) a pair of small knobbed filaments, which stand on the sides of the thorax behind the wings, and which are called *halteres* or balancers, have been regarded as the representatives of the hind wings.



Fig. 181.—Conops.

Of the abdomen in general but little can be said. It consists normally of nine segments; but some of these are generally concealed by the others, so that the abdomen appears to be composed of a smaller number of articulations. In some instances the segments are attached edge to edge, when the abdomen exhibits little or no flexibility; in other cases, each segment slides at its base within the one preceding it, so that the whole is capable of bending to a certain distance in some directions. The orifice of the generative organs is situated at the extremity of the abdomen, which, in the male, is often furnished with peculiar organs for grasping the abdomen of the female during copulation, and in the female with instruments of very various structure, adapted for placing the eggs in the situation most proper for their development. These exquisitely beautiful contrivances will be described hereafter under the different groups of which they are characteristic. The apex of the abdomen is also sometimes furnished with appendages not connected with the generative organs; these are sometimes long filiform tails, sometimes bristle-like organs, by means of which the insect effects considerable leaps. In the Cockroaches, and some other insects, they form stout-jointed bristles, resembling short antennæ. In the Earwigs they constitute a powerful pair of forceps, often of great length; whilst the aphides are furnished with a pair of tubular appendages from which a sweet juice exudes.

The intestinal canal always forms a tube of variable width (Fig. 182), formed of three membranous layers, running from one extremity of the body to the other, commencing behind the mouth in a narrow œsophagus, and usually terminating posteriorly in a somewhat dilated cavity, the *cloaca*, which also receives the termination of the internal generative organs. The œsophagus leads first into a membranous, and usually

folded stomach, the *crop*; from this, in the masticating insects, the food passes into a second stomach, which, from its being furnished with horny plates and other organs for the comminution of the food, has received the name of *gizzard*. Behind this is the

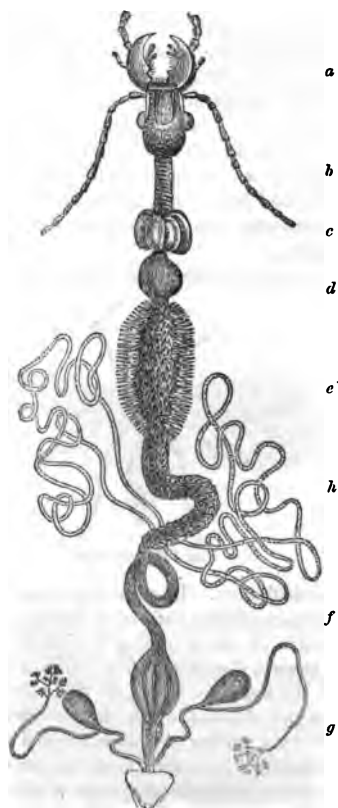


Fig. 182.—Digestive Apparatus of Beetle.

a, pharynx; b, oesophagus; c, crop; d, gizzard; e, chylific stomach; f, small intestine; g, rectum; h, biliary vessels.

true stomach, in which the process of chylification goes on. This is often covered with little villi, or furnished with glandular organs, which appear to secrete a gastric juice of some kind. The remainder of the canal forms the intestine, which is usually of a tubular form, and is very variable in length, sometimes running to the anal opening with but little deviation; whilst in other cases it forms several convolutions in the anterior of the abdomen. The length of the intestinal canal varies greatly. In the carnivorous and suctorial species it is usually short—not more than twice the length of the body—whilst in the vegetable-feeding insects it is much longer, sometimes attaining a length equal to eight times that of the body. The oesophagus is usually furnished with tubular salivary glands, and in the suctorial insects also frequently with a bladder-like organ, the *sucking stomach*, by the dilatation of which the animals are enabled to suck up their fluid nutriment. Behind the stomach the intestine receives the mouths of several long tubular organs, which are usually considered to secrete a matter analogous to bile; whilst the anus is frequently furnished with similar glands, producing an acrid and often offensive secretion.

As insects possess no system of absorbent vessels like those of the higher animals, the portion of the food to be assimilated passes through the walls of the stomach into the cavity of the body,

when it mixes with the blood bathing the surface of the organs, and thus comes into the general circulation. The circulation is effected by very simple means. The heart is a tubular organ running along the back of the insect, and hence called the *dorsal vessel*—(a in the diagram Fig. 183). This is formed of a series of sacs opening one into the other, from behind forwards, in such a manner that the folds formed by the junction of the sacs serve as valves to prevent the reflux of the blood. The blood enters this vessel from the cavity of the body by a series of valvular openings, when it is gradually driven forwards by the successive contraction

of the divisions of the vessel, until it escapes in the neighbourhood of the head. It appears, however, that after this it is no longer confined within vessels, as neither

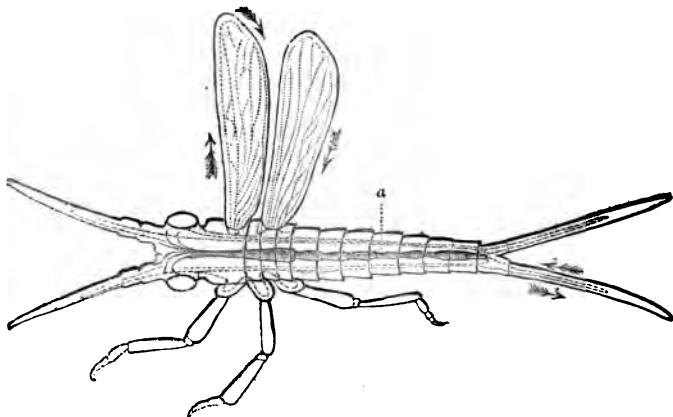


Fig. 183.—Circulation in Insects.

(The arrows indicate the course of the blood).

arteries nor veins have been detected in the bodies of insects, but that it gradually passes back through the spaces left between the internal organs, until it again reaches the heart.

During this return it comes in contact with the respiratory organs, which, in this class of animals, consist of an infinity of minute tubes, which ramify in every direction through the body. These are composed of a membranous outer coat, which is kept constantly distended by a minute cartilaginous filament coiled up in a spiral form (Fig. 184). The air penetrates into them by a number of openings, called *stigmata* or *spiracles*, placed on each side of the body. There is usually one pair to each segment, with the exception of the head, and terminal segments of the abdomen. The spiracles are furnished with a muscular apparatus, by which the insect can close the aperture at pleasure. They are frequently situated on the membrane uniting contiguous segments.



Fig. 184.—Air-tube of Insect.

The most general form of the nervous system in insects is that already described and figured at page 199, Fig. 5, although many of these animals exhibit a striking departure from this general rule. In some the whole of the ganglia of the body appear to be condensed into one or two masses, from the hindmost of which the abdominal nerves radiate in all directions, whilst others present various intermediate stages between this and the normal form. The brain consists of a nervous mass, placed above the oesophagus; and from this the nerves of the principal organs of sense, the eyes and antennæ, are given off. Below the oesophagus is another ganglion, united with the supra-oesophageal ganglia by a pair of nervous threads, which form a collar surrounding the oesophagus. From the lower portion of this ring the filaments are given off which unite the ganglia of the body with those of the head; and these filaments, with their ganglia, always run along the lower portion of the body immediately within the skin

of the belly; the alimentary canal occupying the space above them, and this again being surmounted by the dorsal vessel. Of the organs of sense in these animals we have already spoken. Their marvellous instincts will be described hereafter.

Insects are all unisexual animals. Hermaphroditism, where it occurs, is quite exceptional in its nature, and very rarely gives rise to individuals capable of propagation. The different sexes are sometimes undistinguishable by external characters, except that the females are usually larger and broader than the males; but in most instances the structure of the apex of the abdomen at once indicates the sex, and, independently of characters derived from this part of the body, other organs, especially the antennæ and tarsi, often present very great differences in the two sexes. Their reproduction is also essentially oviparous, although some species are ovo-viviparous—that is to say, the eggs are hatched and the young developed to a greater or less extent within the body of the parent; and a few (the *Aphides*) are truly viviparous at certain periods, the young being produced apparently by a sort of internal gemmation.

In their regular development from the egg, insects in general pass through a certain series of changes, which together constitute what is called the *metamorphosis*, the young

animal on emerging from the egg generally exhibiting an appearance very different from that which it is ultimately destined to assume. The degree of this metamorphosis is, however, very different in different groups of insects. In its most *complete* form, as exemplified in the Butterflies (Fig. 185), Moths, Beetles, and many other insects, the metamorphosis takes place in three very distinct stages. In the first, which is called the *larva* state, the insect has the form of a grub, sometimes furnished with feet, sometimes destitute of those organs. Different forms of insects in this state are popularly known as caterpillars, grubs, and maggots. During this period of its existence the whole business of the insect is eating, which it usually does most voraciously, changing its skin repeatedly to allow for the rapid increase in its bulk; and after remaining

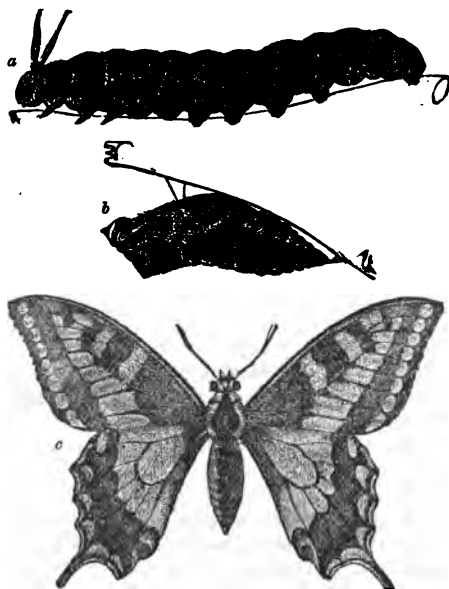


Fig. 185.—Transformations of the Swallow-tailed Butterfly (*Papilio Machaon*). *a*, Larva; *b*, Pupa; *c*, Imago.

in this form for a certain time, which varies greatly in different species, it passes to the second period of its existence, in which it is denominated a *pupa*. In this condition the insect is perfectly quiescent, neither eating nor moving. It is sometimes completely inclosed in a horny case, in which the position of the limbs of the future insect is indicated by ridges and prominences, sometimes covered with a case of a softer

consistence, which fits closely round the limbs, as well as the body, thus leaving the former a certain amount of freedom. Pupæ of this description are sometimes inclosed within the dried larva skin, which then forms a horny case for the protection of its tender and helpless inmate. After lying in this manner, with scarcely a sign of life for a longer or shorter period, the insect, arrived at maturity, bursts from its prison in the full enjoyment of all its faculties. It is then said to be in the *imago* or perfect state. This metamorphosis is one of the most remarkable phenomena in the history of insects, and was long regarded as perhaps the most marvellous thing in nature; although recent researches have shown that the history of many of the lower animals presents us with circumstances equally if not still more wonderful. Nevertheless the metamorphosis of the higher insects is a phenomenon which cannot fail to arrest our attention. To see the same animal appearing first as a soft worm-like creature, crawling slowly along, and devouring everything that comes in its way, and then, after an intermediate period of death-like repose, emerging from its quiescent state, furnished with wings, adorned with brilliant colours, and confined in its choice of food to the most delicate fluids of the vegetable kingdom, is a spectacle that must be regarded with the highest interest; especially when we remember that these dissimilar creatures are all composed of the same elements, and that the principal organs of the adult animal were in a manner shadowed out in all its previous stages.

But although the majority of the class *Insecta* undergo a complete metamorphosis of this description, there are many in which the only transformation consists in a series of changes of skin, without any interval of rest; the larva, which from the first presents a certain degree of resemblance to its parent, gradually acquiring those organs which it originally wanted. In this metamorphosis, which is called *incomplete*, the principal difference between the larva and the imago consists in the absence of wings- (Fig. 186), which first make their appearance in the form of thick lobes, inclosed in cases, in the course of the last changes of the skin. The joints of the antennæ and tarsi are also sometimes fewer in number; and the ocelli, or simple eyes, are generally wanting in the larva, when present in the perfect insect. In some insects, such as the Dragonflies, the May-flies (Fig. 187), and some others, the larvæ, which are aquatic, present a greater difference from the perfect insect than in the cases above referred to; although the pupa is active and continues to feed until the time of its arrival at the imago state. We may therefore call this a *sub-complete* metamorphosis. Lastly, a few insects, which possess no wings in the perfect state, undergo no change, except in size, from the time of their emergence from the egg, to that of their reaching maturity.

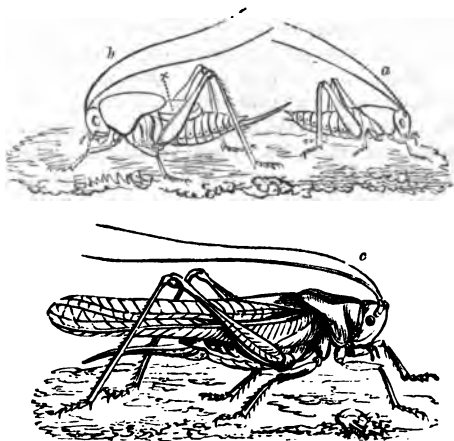


Fig. 186. — Transformations of the Great Green Grasshopper (*Gryllus Viridissimus*). a, Larva; b, Pupa; x, wing lobes; c, Imago.

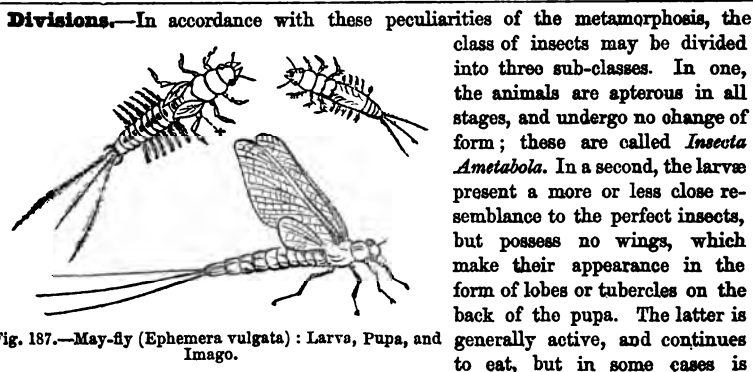


Fig. 187.—May-fly (*Ephemera vulgata*) : Larva, Pupa, and Imago.

Divisions.—In accordance with these peculiarities of the metamorphosis, the class of insects may be divided into three sub-classes. In one, the animals are apterous in all stages, and undergo no change of form; these are called *Insecta Ametabola*. In a second, the larvae present a more or less close resemblance to the perfect insects, but possess no wings, which make their appearance in the form of lobes or tubercles on the back of the pupa. The latter is generally active, and continues to eat, but in some cases is

quiescent; these are the *Insecta Hemimetabola*.

In the third sub-class the metamorphosis is complete; the larva, pupa, and imago states constituting three distinct phases of life; the second being always quiescent. These are the *Insecta Metabola*.

Some entomologists, amongst whom we may mention Professor Burmeister, of Halle, deny the existence of the first of these groups, distributing the insects which form it amongst the orders of the second sub-class; whilst Mr. Westwood arranges the *Ametabola* with the *Myriapoda* in a class distinct from the *Ptilota*, or winged insects; but we have not considered ourselves justified in adopting either of these views.

These sub-classes are further divided into orders principally from characters derived from the structure of the mouth and wings. Of these the *Ametabola* include three,—the *Anoplura*, or Lice, possessing a suctorial mouth; the *Mallophaga*, or Bird-lice, with biting oral organs, but without caudal appendages; and the *Thysanura*, or Spring-tails, with mandibulate mouths, and with two or more bristles attached to the caudal extremity. The *Hemimetabola* include three principal orders, of which one, the *Rhynchota*, including the Bugs and Cicadae, is characterised by the possession of a jointed suctorial rostrum, whilst the other two are mandibulate. In one of these, the *Orthoptera*, the wings are unequal; the posterior membranous pair being the largest, and folded up in repose beneath the anterior pair, which are generally coriaceous in their texture. A second, the *Neuroptera*, has the wings generally equal in size and similar in consistence. Some of these have quiescent pupae. A fourth small order, the *Physopoda*, consisting of minute insects nearly allied to the *Orthoptera*, is characterised by the possession of four narrow flat wings, without nervures, but furnished with a fringe of fine hairs.

The third sub-class, the *Metabola*, is divided into six orders, of which three have the mouth completely suctorial; whilst in the others some of the oral organs are always formed for biting. Of the suctorial *Metabola*, the *Aphaniptera* (a little order including only the Fleas) have the thoracic segments distinctly separated, and the wings represented only by two horny plates on each side of the body.

In the two other suctorial orders the segments of the thorax are more or less completely fused into a mass. Of these, the *Diptera*, or Flies, are distinguished by their short proboscis, and by the possession of only a single pair of wings; the position of the hinder pair being occupied by knobbed filiform organs; whilst the *Lepi-*

diptera, including the well-known Butterflies and Moths, are furnished with a spiral trunk, and with four large scaly wings (Fig. 185). Of the mandibulate orders of this section, the *Hymenoptera* are characterized by their four more or less membranous veined wings, of which the posterior pair are always the smallest; whilst the *Coleoptera*, or Beetles, are distinguished by the horny consistency of their anterior wings, which serve merely as cases for the protection of the delicate membranous hinder pair. A third mandibulate order, the curious *Strepsiptera*, or Bee-parasites, apparently allied to the *Coleoptera*, have the anterior wings reduced to a rudimentary condition, forming a pair of singularly twisted appendages placed on the mesothorax; whilst the hinder wings are of large size, and fold up like a fan during repose. The females are apterous.

SUB-CLASS I.—AMETABOLA.

ORDER I.—ANOPLURA.

Neither the habits nor the appearance of the insects forming the present order are such as to render them particularly attractive objects. Small as they are, perhaps no other insects inspire so much disgust as Lice; being generally regarded as the concomitants of dirty habits. They have a flattened and semi-transparent body, with a distinctly separated head, which bears a pair of short five-jointed antennæ and one or two simple eyes on each side, and is furnished beneath with a soft retractile proboscis, within which are four bristle-like organs, the analogues of the mandibles and maxillæ. There is rarely any distinction between the thoracic and abdominal segments, except that the former are furnished with three pairs of stout legs, terminated either by a strong hook or by a pair of clasping claws (Fig. 188).

These animals are all parasitic upon mammiferous animals, of which almost every species has its peculiar louse, whilst some of them harbour three or four distinct species of these parasites. Four species inhabit the human subject, three of them being of ordinary occurrence, whilst the fourth, the *Pediculus tabescentium*, has only been occasionally observed, but always in vast numbers, either causing or accompanying a complaint under which the patient appears gradually to waste away. Several instances are recorded in ancient authors of death being caused by this disease, which is termed *phthiriasis* (from the Greek *phtheir*, a louse); and although, in some of these cases, the mischief appears rather to be attributable to mites, allied to the *Sarcoptes scabiei* (page 319, Fig. 147), yet the occurrence of vast quantities of *Pediculi* upon an old woman, which was observed some years since at Bonn, would seem to show that true Lice may have been the aggressors in some of the fatal cases on record.

These insects generally infest those parts of their hosts which are most thickly covered with hair, amongst which they creep about with ease by means of their grasping claws. They attach their eggs, which are of a pear shape, to the hairs, and

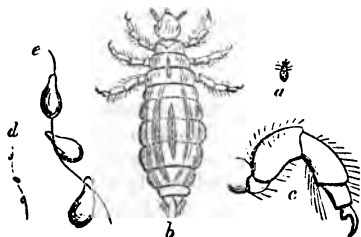


Fig. 188.—a, the Common Louse; b, magnified; c, one of the legs magnified; d, eggs; e, ditto magnified.

the young are excluded in a few days. They undergo no metamorphosis, and are soon capable of reproduction; so that their numbers rapidly increase, when proper measures for their eradication are neglected. Burmeister arranges the *Anoplura* with the *Rhynchota*.

ORDER II.—MALLOPHAGA.

General Characters.—This small order is composed of insects bearing a general resemblance to the Lice, with which, in fact, they are arranged by many authors; whilst Burmeister, whose system admits no orders of apterous insects, places them with the *Orthoptera* in his order *Gymnognatha*. They differ from the *Anoplura*, in having the mouth always formed for biting, being furnished with a pair of hooked mandibles, and distinct upper and lower lips, and sometimes with a slender pair of palpigerous maxillæ. This difference in structure is accompanied by a corresponding difference in habits. Instead of sucking the blood of the animals on which they are parasitic, the *Mallophaga* devour the most delicate portions of their hair or feathers; frequently attacking these organs at the moment of their sprouting through the skin. They are especially common upon birds, few of them being free from such parasites; and some species also infest quadrupeds. As nearly every species of bird has at least one of these parasites peculiar to itself, their numbers, as might be expected, are by no means small, and they have been formed into numerous genera. Burmeister divides them into two families—the *Phlebotoridae*, with filiform antennæ, and without maxillary palpi, and the *Liotheidae*, with maxillary palpi and clavate antennæ.

ORDER III.—THYSANURA.

General Characters.—This order includes a small number of mandibulate insects, referred by Burmeister, like those of the preceding order, to the neighbourhood of the *Orthoptera*. They are distinguished from the other *Ametabola* by the possession of caudal appendages, by means of which most of them are enabled to execute considerable springs. The body is clothed with hairs or scales. The head is sometimes free, sometimes concealed beneath the prothoracic segment. The eyes, in some species, are compound; but the majority are only furnished with a group of simple eyes on each side of the head; and the mouth is composed of an upper and lower lip, a pair of mandibles, and a pair of maxillæ; the lower lip and maxillæ being usually furnished with palpi.

Divisions.—They form two families—the *Poduridae*, or Spring-tails, and the



Fig. 189.—Podura.

Lepismidae. In the former the caudal appendage has the form of a forked tail (*Podura*, Fig. 189), which is bent under the animal when not in use, and by its sudden extension causes the animal to spring, often to a great distance in comparison with its size. The head is distinct; the antennæ short, and generally four-jointed; the simple eyes six or eight on each side; and the palpi very short, and composed only of a single joint. The

body is covered with numerous minute scales, often of a beautiful silvery or pearly lustre, and curiously striated, which are frequently employed as test objects for the microscope. The insects usually live in moist places, under leaves, in considerable numbers. Some species may be found jumping about on the surface of the water, whilst others are met with in profusion upon snow and ice.

The *Lepismidae* (*Machilis*, Fig. 190), have a spindle-shaped body, usually covered with silvery scales, and furnished along the sides of the abdomen with a series of appendages or false feet, besides several long, jointed, bristle-like organs at its extremity. The head is concealed under the prothorax: the eyes are usually compound, and frequently occupy the whole of the head; the antennæ are very long, and composed of numerous joints; and the maxillary palpi, which consist of from five to seven joints, are very conspicuous.

These insects generally inhabit moist places under stones, in woods, and similar localities. The most common species, *Lepisma Saccharina*, is frequently found about houses, especially in sash frames. They are very active, and many of them jump well; but they generally conceal themselves during the day, and seek their food, which appears to consist of vegetable matter, by night.

SUB-CLASS II.—HEMIMETABOLA.

The majority of the insects of this sub-class are active in all stages of their existence; and, as a general rule, the principal differences between the larva at its exclusion from the egg, and the perfect insect, consist in its smaller size, and in the absence of wings. In the last order of this section, the *Neuroptera*, the difference between the larva and the perfect insect becomes greater, and in some of these insects the pupa stage is passed in a quiescent state; but in these the pupæ still retain the power of motion.

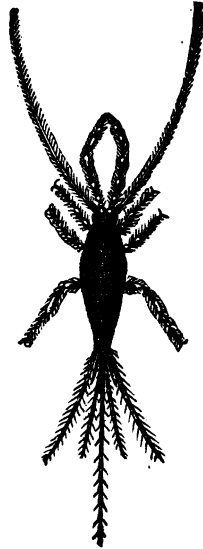


Fig. 190.—*Machilis*.

ORDER IV.—RHYNCHOTA.

General Characters.—The order *Rhynchota*, corresponding with the *Hemiptera* of Latreille, is distinguished from the other insects with an imperfect metamorphosis, by the possession of a suctorial mouth. This consists of a more or less flexible jointed rostrum, composed of the labial palpi, which forms a sheath within which four bristles, the analogues of the mandibles and maxillæ, are contained and protected from injury. By means of these bristles the insect wounds the plants or animals upon the juices of which it feeds, and the fluid nutriment is then sucked up by the action of an inflated appendage of the œsophagus. The head always bears a pair of compound eyes, and usually either two or three ocelli.

Most of these insects possess four wings, which vary considerably in their structure. The segments of the thorax are usually distinctly separated. The legs are generally formed for walking; but the anterior pair are sometimes converted into raptorial organs; and in the aquatic species the hinder legs are generally flattened, and fringed with bristles, to render them efficient organs of natation.

Divisions.—The order *Rhynchota* may be divided into two sub-orders, which, in fact, have frequently been regarded as distinct orders, especially by English entomologists. In the first, the *Homoptera*, the anterior wings are usually of similar consistence throughout, and the mouth is turned backwards, so that the rostrum springs from the base of the head, and, in some instances, apparently from the breast. In the second

sub-order, the *Heteroptera*, the anterior wings are almost always of a horny consistence from the base to the middle, or even further; the remainder of the wing being membranous, and the line of demarcation between the two parts perfectly distinct; in these the rostrum springs from the anterior portion of the head.

SUB-ORDER I.—HOMOPTERA.

The Homoptera form three great groups or tribes. The first, the *Coccina*, is composed of numerous minute insects, of which the history is still very imperfectly known. Of these the tarsi have only one joint. The males are furnished with two wings, with a few straight nervures; they are destitute of a rostrum, and pass their pupa stage in a state of repose. The females are destitute of wings, possess a rostrum, and appear to undergo no metamorphosis whatever. These curious little creatures, whose history is so singular that some authors have proposed the formation of a separate order for their reception, are principally inhabitants of the warmer regions of the earth, although many species are found in our own country, where some of them are well known to gardeners under the name of "the bug," from the injury they do to many plants, especially in hot-houses.

Nothing can well be more dissimilar in appearance than the two sexes of these singular insects (Fig. 191). The females usually form a mere fleshy mass, often nearly destitute of limbs, and remaining attached to one spot upon the branches of the plant infested by them, from which they continue to suck nutriment, by the agency of

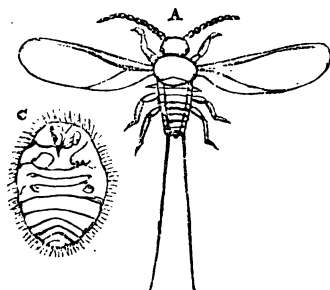


Fig. 191.—Cochineal Insect (*Coccus cacti*).
A, male; C, female.

their rostrum, until they attain a considerable size. The males, on the contrary, are generally very minute and really elegant creatures, furnished with a single pair of filmy wings; the only representatives of the hinder wings being a pair of organs somewhat similar to the *halteres* of the *Diptera*. Hence some entomologists have put forward the opinion that the males of the *Coccina* are, in reality, dipterous parasites; but this view is quite untenable. The abdomen of the male is generally furnished with a pair of long filaments. In some instances the females retain their limbs and

power of motion through life.

The larvæ of these insects are minute, oval creatures, resembling little Woodlice, which creep freely about the plants they inhabit, and live without any apparent change through the winter,—at least this is the case in one British species (the *Coccus aceris*), as observed both by Mr. Westwood and the author. In the spring the females become remarkable by their increased size; they attach themselves to the branches of the sycamores, on which they live, and gradually swell until they resemble fleshy excrescences, about the size of a small pea. At the same time the males change to the pupa state beneath the skin of the larva, which then resemble little oval scales attached to the bark. In the month of May the males acquire their full development, and when nearly ready for exclusion their little white tails may be seen projecting from beneath the grayish case formed by the skin of the larva. They emerge backward, so that the wings are pulled up over their heads, and immediately on leaving

their case they seek the female. After the impregnation of their disproportionate partners, the great end of their existence, the males disappear; but the females continue growing for some time, and at last lay their eggs in the midst of a mass of white cottony matter, between the bark of the tree and the lower surface of their own bodies. The latter at length become nothing but dry convex shells, beneath which the young are hatched. The development of the other species of the order is very similar.

Nor is the singularity of their natural history the only claim that these insects have upon our attention. Lowly as they may be, in point of organization, there are few insects that exceed them in commercial importance. The finest red dyes known to our manufacturers are derived from these creatures. The *Lecanium Ilicis*, which inhabits the *Ilex* or ever-green oak of the countries round the Mediterranean, was employed for this purpose by the ancient Greeks and Romans, as it is still by the Arabs; and until the introduction of the Mexican cochineal, another species, the *Porphyrophora polonica*, which lives on the roots of the *Scleranthus perrennis* in Central Europe, was much used for the same purpose. The Mexican cochineal, which has driven the others out of the field, is also a species belonging to this group, the *Coccus cacti* (Fig. 191), which lives as a parasite upon the Nopal, or *Cactus opuntia*—a plant very common in Central America. The commercial importance of this insect is shown by the fact, that in 1850 no less than 2,514,512 lbs. of cochineal were imported into Great Britain alone; and as about 70,000 insects are supposed to be contained in a pound of this substance, we may form some idea of the numbers annually destroyed. For many years the cultivation of cochineal was entirely confined to Mexico; but the insect has lately been introduced into Spain and the French possessions in Africa, with some prospect of success. A fourth species, of great importance, is the lac insect (*Coccus lacca*), an inhabitant of the East Indies, where it feeds upon the Banian-tree (*Ficus religiosa*), and some other trees. To this insect we are indebted, not only for the dye-stuffs known as *lac-dye* and *lac-lake*, of which upwards of 18,000 cwts. were imported in 1850, but also for the well-known substance called *shell-lac*, so much used in the preparation of sealing-wax and varnishes. In all these cases it is only the female insects that yield the colouring matter.

In one genus of *Coccina* (*Dorthisia*), several species of which are found in this country, the female—which, although apterous, is active in all stages—is completely covered with a snow-white secretion, which gives it more the appearance of a little plaster-cast than anything else.

In a second tribe, the *Phytophthiria*, or Plant-lice, both sexes are either wingless or furnished with four distinctly veined wings. The rostrum springs apparently from the breast, and the tarsi are two-jointed and furnished with two claws.

The greater part of this tribe is composed of the *Aphides*, or Plant-lice (Fig. 192), whose extraordinary history renders them one of the most interesting groups of insects. These creatures must be well known to every one. They are all small animals, with a more or less flask-shaped body, furnished with six feet and a pair of antennæ, and usually with a pair of short tubes close to the extremity of the abdomen, from which a clear sweet secretion exudes. Both sexes are sometimes winged, sometimes apterous; and the individuals of the same species are often winged and apterous at different periods of the year. They all live upon plants, the juices of which they suck; and when they occur in great numbers, often cause great damage to vegetation. Gardeners



Fig. 192.—*Aphis Rosæ*.

and farmers are well aware of this. Many plants are liable to be attacked by vast swarms of *Aphides*, when their leaves curl up; they grow sickly, and their produce is certain to be greatly reduced. One striking instance is presented by the Hop-fly (*Aphis Humuli*). The cultivation of hops is notoriously a most uncertain business; and this uncertainty is mainly caused by the occurrence, in some seasons, of vast numbers of these minute insects; whilst in others very few are to be seen. So great is this deficiency sometimes, that the amount of duty paid upon hops, in different years, has varied between £15,400 and £468,000, indicating, of course, a corresponding variation in the amount of the crops. Many species also attack the roots of plants, where their presence is speedily indicated by the gradual withering of the foliage. Lettuces, amongst garden vegetables, are especially subject to these visitations.

The sweet fluid, which exudes from the tubular process of the abdomen of these insects, is often in such abundance that it drops upon the leaves of the plants frequented by them, and even to the ground. It is well known by the name of *honey-dew*. Ants have a particular fondness for this fluid, and may constantly be seen upon trees and plants frequented by *Aphides*, stroking them with their antennæ, apparently to induce them to furnish a supply of the coveted fluid. From this circumstance the *Aphides* have been termed the Ant's milch-cows; and they are said to tend them with as much care as would be bestowed by a human farmer upon his cattle. Wasps also have been observed similarly engaged.

But the most singular portion of the history of these insects is their very curious manner of propagation. In the autumn, male and female insects are found, furnished with perfect generative organs; these copulate, when the females lay eggs, which are hatched the following spring. But, instead of producing individuals of both sexes, these eggs give birth only to female animals, which produce living young without any congress with the male; the brood thus brought forth again produces living young in the same manner, and this goes on throughout the whole summer, without the appearance of a single male insect. In the autumn again, male and female individuals are produced, and the latter lay eggs which are to continue the species until the following summer. This succession of fruitful virgins, as they have been termed, was traced by Bonnet through nine, and by Duvau, in seven months, through eleven generations, when the experiments were cut short by the cold of the approaching winter; but Kyber, a German naturalist, by keeping a colony of *Aphides* in a warm room, observed this mode of reproduction during a period of four years without once seeing a male insect. The young ones thus produced grow rapidly, and change their skins three or four times; so that in a few days they are in a condition to continue their race, and the numbers of a colony often increase so rapidly that the plant on which they have established themselves is completely destroyed.

Few phenomena in natural history have presented more difficulties to physiologists than this, and many have been the theories advanced to account for it. Some have imagined that the viviparous *Aphides* were hermaphrodites, whilst others have recurred to the doctrine of spontaneous generation. Some have supposed that by some mysterious process the original copulation was sufficient to fecundate all the ova to be produced from the descendants of that union for a certain number of generations, when its virtue being exhausted, males and females made their appearance as a last generation; whilst Steenstrup regarded the reproduction of the *Aphides* as an instance in support of his doctrine of the alternation of generations (see pages 252 and 254). We have not space for the discussion of this curious question, which is of great physiological im-

portance. We shall merely state that a modification of Steenstrup's view is probably the correct one, as recent researches, especially those of Dr. Burnett,* appear to prove that the viviparous *Aphides* possess no ovarian organs, and that their young are formed by a process of gemmation in the interior of the abdomen,—a process which Dr. Burnett regards as analogous to the budding of the *Medusa* from their Hydroid polypes.

The legs of the *Aphides* are long, but weak, and their motions are confined to a slow march upon the leaves and stems of plants; but another family of plant-lice, the *Psyllida*, have the hinder thighs much thickened, so as to form powerful springing organs.

In the third section, the *Cicadaria*, which includes a great variety of animals, the tarsi are three-jointed, the antennæ usually minute and terminated by a bristle; and the wings, which are four in number, are furnished with numerous nervures, forming several cells. The anterior wings are sometimes of a leathery texture, and generally of a firmer consistence than the hinder pair, which they cover and protect during repose. The rostrum is always distinctly attached to the head, and never, even apparently, springs from the front of the breast. The great diversity of form presented by these animals has led to the establishment of many families; but we can only indicate the four principal groups into which they are divided by authors.

The first of these, the *Cicadellina*, or *Cercopidæ*, of which the *Aphrophora Spumaria* (Fig. 193), or common Frog-hopper, is a well-known British example, have the antennæ placed between the eyes, and the scutellum visible—that is to say, not covered by a process of the prothorax. The ocelli, which are sometimes wanting, are never more than two in number. These little creatures are always furnished with long hind legs, which assist them in performing most extraordinary leaps. The posterior tibiæ of many species are armed with a double row of spines. A species nearly allied to that here figured (the *Aphrophora bifasciata*) is very abundant in gardens. The larva envelops itself in a frothy secretion, which has received the name of *Cuckoo-spit*; and this denomination has been extended to the insects. An immense number of the species of this group are to be met with almost everywhere.

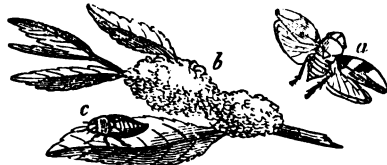


Fig. 193.—Frog-hopper (*Aphrophora spumaria*).
a, imago; b, frothy secretion; c, pupa.



Fig. 194.—a, *Bocydium globulare*; b, *B. cruciatum*.



Fig. 195.—*Fulgora laternaria* (reduced).

The *Membracina*, forming the second group, resemble the preceding in most of their

* Dr. Burnett's important paper appeared in Silliman's American Journal for January 1854, and was reprinted in the Annals of Natural History for August, in the same year. It contains original observations, accompanied by a general résumé of the subject.

characters, but have the back of the prothorax produced into a singular process, which often covers and conceals not only the scutellum but the whole upper part of the insect. This prothoracic process often assumes the most remarkable forms, two of which are represented in Fig. 194. Both these insects inhabit Brazil; and most of the species of this group are found in tropical countries, two only inhabiting Britain.

In the third group, the *Fulgorina*, the antennæ are placed under the eyes, and the ocelli are only two in number. This group includes the Lantern-flies (*Fulgoræ*), of which a large species, inhabiting Guiana, the *Fulgora laternaria* (Fig. 195) is said to emit considerable light in the dark. This account rests principally upon Madame Merian's statement, and appears never to have been observed since her time; so that the generality of entomologists are disposed to doubt the occurrence of the phenomenon. The light is said to be produced from the singular prolongation of the head, which is common to this and many other species, exhibiting most extraordinary forms in some instances. A well-known example of the genus *Fulgora* is the *F. candelaria*, constantly to be seen in boxes of Chinese insects. Many of the *Fulgorina* are of large size, and decorated with most brilliant colours; but these are all inhabitants of warm climates. The European species are small, and generally very dingy in their appearance.

The fourth group is distinguished from all the rest by the possession of three ocelli. The antennæ are placed in front of the eyes. These insects are called *Stridulantia*, from the faculty they possess of producing a chirping noise, which, as they are generally of large size, is often exceedingly loud and disagreeable. Nevertheless, the ancients, and especially the Greeks, appear to have regarded this music, which is very unpleasant to modern ears, with feelings of great satisfaction; and the *Cicada* is often referred to by the Greek poets. Anacreon, in particular, has devoted an ode to singing the happiness of this insect. An element of this happiness, according to another Greek poet, is, that the *Cicada* "all have voiceless wives," an opinion which will probably find supporters in the present day. This shows that the ancients were well aware that only the male *Cicada* possessed the musical talent which they seem to have admired so much. The apparatus, by which the sound is produced, consists in a sort of a drum placed in a cavity on each side of the base of the abdomen; this is pulled inwards by the action of a particular muscle, and on being again let loose its vibration produces a loud, sharp tone. The drums are concealed by scale-like plates, which are sometimes so large as to reach nearly to the extremity of the abdomen.

The female lays her eggs in slits, which she cuts in the bark of trees by means of a curious saw-like ovipositor; these are generally so weakened by the operation that they fall to the ground, when the larvæ burrow down to the roots of trees, upon which they feed, often occasioning considerable damage. They appear to occupy at least two years in their development. An American species is very remarkable from its appearing only once in seventeen years in the same locality, apparently passing the interval in its preparatory stages. Hence it is known, in the United States, as the *Seventeen-year Locust*. Its scientific name is *Cicada septendecim*.

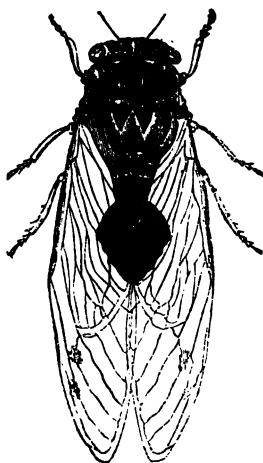
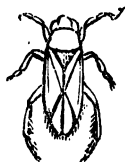


Fig. 196.—Cicada.

SUB-ORDER II.—HETEROPTERA.

The *Heteroptera*, or Bugs, form two principal groups, distinguished by their structure and habits,—the *Hydrocores* or Water-bugs, and the *Geocores* or Land-bugs. The former are at once recognizable by the small size of their antennæ, which are composed of three or four short joints, and concealed beneath the eyes. Of these, the *Notonectida* are distinguished by their broad, rounded head, which occupies the whole width of the front of the body. They swim rapidly about in the water, with their bellies directed upwards, rowing themselves along by means of their flattened hinder legs, which are extended on each side of them like oars. Hence the *Notonecta* (Fig. 197), is generally known as the *boat-fly*. They carry the air required for their respiration in a space left for this purpose between the wings and the back. They are very active and predaceous animals, and when captured some of them often inflict a painful wound with their powerful rostrum. Several species may be met with in almost any piece of water. In the second group, the *Nepina*, the head is small and triangular, and generally considerably narrower than the thorax. Their legs are generally less distinctly formed for swimming than in the preceding group; but the anterior pair are converted into powerful raptorial organs; as the *Nepina*, although much slower in their movements, are quite as predaceous in their habits as the *Notonectida*.

Fig. 197.—*Notonecta*.Fig. 198.—*Nepa cinerea*.

The *Nepa cinerea* (Fig. 198) is a British example of this group, which may be met with in every pond. These insects respire by means of the filaments attached to the caudal extremity, which they place at the surface of the water, the only available stigmata being situated at the base of these filaments.

In the *Geocores*, or Land-bugs, for which Mr. Westwood has proposed the name of *Aurocorisa* (Air-bugs), as more appropriate,

some of the species inhabiting the surface of the water, the antennæ are never concealed, and the legs are always formed for running. When disturbed or irritated most of them emit a most offensive odour, which no one who has ever had the misfortune to have any dealings with the common Bed-bug will be likely to forget. These insects form nine principal groups, of which the first four have the rostrum of three joints, whilst in the remainder this organ is composed of four articulations. The species with a three-jointed rostrum are, for the most part, predaceous in their habits; whilst those with four joints generally feed upon vegetable juices.

The nearest approach to the Water-bugs appears to be made by the *Ploteris*, a group of bugs with a boat-like body and very long legs, which may be constantly seen running about upon the surface of ponds and quiet rivers. They are distinguished from the other *Heteroptera* by having the claws inserted at some little distance from the apex of the last joint of the tarsi. Some species have been taken on the surface of the sea at a great distance from land. Another group, the *Riparia*, is formed of small oval bugs, often met with in the mud at the sides of ponds; a third, the *Reduvina*, is distinguished by having the head produced behind the eyes into a distinct neck. This group includes the most predaceous and some of the largest of the *Geocores*. The rostrum is usually stout, and is said to inflict a most severe wound. In the *Mem-*

brancea, to which the common Bed-bug belongs, the rostrum is inclosed in a sort of canal, formed by two little ridges running down between the bases of the legs.

Of those groups with a four-jointed rostrum, two are destitute of ocelli or simple eyes. Of these, one (the *Bicelluli*) is composed of a great number of small insects, which may usually be found upon plants in great profusion during the summer months. They are distinguished by having the nervures of the membranous portion of the hemelytra formed into two basal cells. The two last joints of the antennæ, which are composed of four joints, are generally very slender. In the second group, the *Cæcigenia*, the membrane is furnished with numerous parallel nervures, and the four joints of the antennæ are nearly of equal thickness. These insects are generally of a bright scarlet colour, adorned with black spots. One species is found in England.

The same colours not unfrequently occur in the next group, the *Lygæodea*, which, however, possess ocelli. These are further distinguished by the insertion of their antennæ upon the sides of the head, below a line drawn from the eyes to the rostrum, and by the membrane of the hemelytra never having more than four or five nervures. Numerous species occur in Britain. The *Coreodea* are distinguished from the preceding group by the insertion of their antennæ higher up on the sides of the head, and by the presence of numerous nervures in the hemelytral membrane. The scutellum is usually small and triangular, and the antennæ are always composed of four joints. The majority of these insects inhabit hot climates, where many of them attain a large size. Some of them are remarkable for strangeness of form, but very few for brilliant colouring. The European species are all small.

The *Scutata*, the last group of the order, includes some of the most brilliant creatures contained in it, or perhaps in the entire class of insects. Their most striking character consists in the large size of the scutellum, which in all cases reaches the base of the hemelytral membrane (Fig. 199), and in some instances is so large as to cover all the upper surface of the body, serving as a sheath for the protection of the wings. The antennæ are usually composed of five joints, and are almost always inserted beneath a projecting margin of the sides of the head. The rostrum is frequently long, sometimes longer than the body. This group includes a great number of species, most of them of considerable size. The majority inhabit warm climates, to which the species with the very large scutellum are almost confined. Amongst these the *Callideæ*, which are of a brilliant golden green colour, with black spots, rival the most splendid butterflies in beauty.



Fig. 199.—*Halya Mucorea*.

ORDER V.—PHYSOPODA.

General Characters.—The small order *Physopoda* includes some minute insects which were placed by Linnæus, Fabricius, and most of the older entomologists, in the same order with the *Rhynchota*, their mouth at the first glance bearing a certain amount of resemblance to a minute rostrum. Later observations proved, however, that the structure of their oral organs was quite different from that presented by the *Rhynchota*; and they have since been generally placed in the neighbourhood of the *Orthoptera*. Burmeister included them in his order *Gymnognatha*, with the other mandibulate Hemimetabolous and Ametabolous insects.

The *Physopoda* are generally furnished with four nearly equal, flat wings, destitute of reticulations, but usually fringed, especially at the apex, with numerous fine hairs. Some species, however, are apterous. The head (Fig. 200) bears a pair of large, granular, compound eyes, between which there are usually three ocelli. The antennæ are generally composed of about eight joints, and are attached to the front of the head between the eyes. The lower part of the head is bent back under the breast, and the mouth is situated at its hinder extremity; so that the resemblance to the *Homoptera* is tolerably complete. The organs of the mouth consist of a large triangular upper lip, behind which a pair of curved, bristle-shaped mandibles is situated; the maxillæ are small, usually attached to the labium, and like this bear a pair of jointed palpi. The presence of the latter organs will always distinguish these insects from the *Rhynchota*. The tarsi are composed of two joints, the last of which is destitute of claws, but furnished with a soft vesicular organ, which enables the insects to adhere firmly to any object upon which they are walking. It is from this structure that the name of *Physopoda*, given to this order, is derived (Gr. *phusa* a bladder, *pous* a foot).

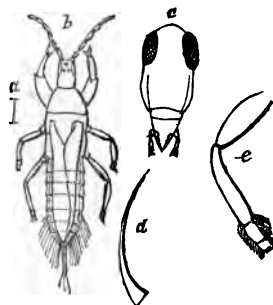


Fig. 200.—*Phlebotrips*.
a, natural size; b, insect magnified;
c, head; d, mandibles; e, leg.

These insects are found upon most plants, generally in the flowers, which they appear to visit in search of the sweet fluid generally to be found in such situations. They run quickly, and often perform considerable leaps by the assistance of the abdomen, which is employed in the same way as the furcate appendage of the *Poduræ*. Many of them, not content with such light nourishment as the nectar of flowers, inhabit the foliage and stems of plants, to which they often do a great deal of mischief. One species, the *Thrips cerealium*, has frequently done considerable damage to the wheat crops, both in this and other countries, sometimes attacking the grain in the ear, and sometimes gnawing the tender stems. Others, of which the species represented in our figure (Fig. 200) is an example, are found upon and under the bark of trees.

Divisions.—Mr. Haliday divides these insects into two tribes. In the first, the *Tubulifera*, the terminal segment of the abdomen is tubular in both sexes; whilst the females of the second, the *Terebrantia*, are furnished with a valvular serrated ovipositor.

ORDER VI.—ORTHOPTERA.

General Characters.—The *Orthoptera* form the first order of the Hemimetabolous insects, in which the mouth is unmistakably formed for biting. The head is usually large and perpendicular, furnished with a pair of antennæ of very variable length (generally long and composed of numerous joints), with a pair of large compound eyes, and usually with two ocelli. The mouth is usually of very powerful construction; the mandibles strong, horny, and toothed; the maxillæ large, with the apex half concealed by a hood-like, horny lobe, and each bearing a long five-jointed palpus; the upper and lower lips are large, and the latter is furnished with a pair of three-jointed palpi, and usually with one or two additional pairs of palpiform lobes. The segments of the thorax are distinct, the anterior segment, or prothorax, being generally of large size. The remaining segments are usually concealed under the wings, which, when

present, are four in number, the anterior pair smaller than the posterior, and generally

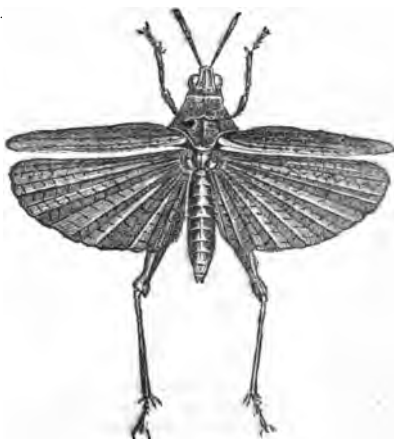


Fig. 201.—Locust, with wings expanded.

of a leathery or parchment-like texture, serving as a protection for the latter, which, in repose, are folded up in a fan-like form. The anterior wings almost always lap over each other at the apex, and both pairs are traversed by distinct reticulated nervures. The principal nervures of the hinder wings always radiate from a central point to the circumference (Fig. 201). The legs vary greatly in form. Some species are exclusively formed for running (Cockroaches, Earwigs), all the legs being of nearly equal size; in others the anterior pair are greatly enlarged and converted into raptorial organs (*Mantis*), the insect running upon the other four legs; whilst in others, again (Grass-hoppers, Locusts, Crickets), the hinder legs, and especially

the thighs, are of very large size, enabling the insects to execute great leaps. The number of joints in the tarsi varies from three to five. The metamorphosis of these insects has already been described (page 341, Fig. 186).

Divisions.—The *Orthoptera* fall readily into two great sections—namely, the *saltatorial* and *cursorial Orthoptera*. The former (in which the hind legs are always elongated and converted into leaping organs, and the tarsi never composed of more than four joints) include three tribes,—the *Locustina*, the *Gryllina*, and the *Achetina*. They are all herbivorous insects.

In the *Locustina* the tarsi are three-jointed; the antennae short, and composed of from twenty to thirty joints; and the females have no apparent ovipositor. The head is usually furnished with three ocelli. Few insects are more dreaded by the inhabitants of the warmer regions of the earth than those Locusts, which, from their often collecting in vast swarms, and moving onwards with a steady and irresistible progress, quickly destroy every trace of vegetation over a vast extent of country; thus reducing the husbandman to despair, and converting the smiling face of nature into a desolate wilderness. A district, over which one of these devastating swarms has passed, is said to appear, to the eye of an observer, as though every vegetable production which once decked its surface had been completely burned off the ground; hence the Latin name of the insect (*Locusta*, from *locus ustus*, a burnt place) is peculiarly appropriate. Eastern countries, and especially those in the neighbourhood of the Levant, appear to be most exposed to the ravages of these destructive insects; and we find many highly poetical references to them in the writings of the Hebrew prophets, wherein this appearance of burning is expressly mentioned. When the vegetation of the place first devastated by these creatures is entirely destroyed, they take to flight in countless multitudes towards some other devoted spot, often forming clouds of several hundred yards across, which, in their passage, sometimes conceal the light of the sun. When engaged in the work of destruction they are said to produce a sound resembling that of a strong flame driven by the wind, and the spot upon which they have alighted is

almost immediately denuded of every thing green. The descent of a hostile army is less dreaded in the countries subject to these visitations, than the appearance of the hests of the Locusts, which were regarded by the ancients, both Jews and pagans, and are still so by the Arabs, as the avenging armies of the Deity. The modern Arabs, in fact, declare that the Locust bears a statement to this effect, in good Arabic, in the markings on its wings. The best known species is the *Locusta migratoria* (Fig. 177), which has occasionally found its way into Central Europe, and even to our own island; but in the south of Europe this insect is a formidable enemy to agriculture, and a considerable amount is there annually paid in rewards for its destruction.

The inhabitants both of Asia and Africa, where Locusts particularly abound, use these animals as a common article of food. They generally pull off the legs and wings, and fry the bodies in oil or butter, and a dish of Locusts well prepared is said to be regarded as somewhat of a delicacy in those countries. The Locusts are also occasionally dried, pounded, and used as flour. Many of our British Grasshoppers belong to this tribe; some of them (*Tetrix*) have the back of the prothorax produced backwards into a pointed process as long as the abdomen. The migratory Locust measures about two inches and a half in length, and some other exotic species are much larger; the *Locusta cristata*, a very beautiful species common in the Levant, being four inches long, and between seven and eight in expanse of wings. Our British species are generally of comparatively small size. Nearly all of them produce a loud chirping noise, by rubbing the inside of the thigh against the elevated nervures of the wing covers; but beyond this they possess no special apparatus for the production of sound.

Some species (*Truxalis* and *Proscopia*) are remarkable for the form of their heads, the front of which is produced into a conical process, bearing the eyes and antennae at or near its summit. The antennae, which are generally thread-shaped, are sometimes thickened at the base, and sometimes clavate.

The insects composing the second tribe (the *Gryllina*), of which a British species has already been figured (Fig. 186), resemble the *Locustina* in having their wings arranged during repose in a roof-like form; but are at once distinguishable from them by the structure of the antennae, which, instead of being short, cylindrical, and stout, are of great length, generally very slender, and tapering to a fine point. The females, also, are furnished with an external ovipositor (see Fig. 186), and the males have a singular talc-like spot, surrounded by elevated nervures, at the base of each wing-cover, by the mutual friction of which their chirping is effected. These two plates are not exactly similar, and the insect, in consequence, cannot produce his shrill music indifferently with either wing-case uppermost; the right wing-case is usually laid over the left one. The tarsi are four-jointed. The ocelli are generally wanting.

The ovipositor of the female is a sword-shaped organ, composed of several plates attached to the extremity of the body, which also bears a pair of short caudal appendages in both sexes. The female pushes the ovipositor a considerable distance into the earth, forming a narrow cavity in which she lays several eggs. She then proceeds to another spot, and repeats the operation.

The *Gryllina* appear to frequent trees and shrubs more than either of the other two tribes, the members of which generally keep amongst herbage; and, in accordance with this habit, many of the exotic species have wing-cases, which present the most perfect resemblance to leaves, both in colour and veining. There are several British species, one of which (*Gryllus viridissimus*, Fig. 186) is common in autumn in many marshy situations. It is one of the largest British insects, being about two

inches in length, and three and a half in expanse of wings; and, notwithstanding the vegetable nature of its ordinary diet, two of them can scarcely be put together without a battle, when the victor very often makes a meal off some of his antagonist's limbs; and Mr. Westwood mentions an instance, in which a specimen of this insect, which had been inclosed in a box with one of his own hind-legs, was found to have devoured about half of it in the course of the night. Another species (the *Decticus verrucivorus*) which has occasionally been found in this country, received its specific name, which signifies "wart-eater," from a belief current amongst the peasantry of the continent of Europe, where the insect is common, that its bite, assisted by a brownish liquid which it emits from the mouth, is a certain cure for warts.

Of the tribe *Achetina*, the common Cricket (*Acheta domestica*, Fig. 202), the noisy little denizen of our kitchen hearths, may serve as an example. These insects, like those of the preceding tribe, have the antennæ slender and tapering, and often considerably longer than the body. They also agree with the *Gryllina* in the structure of the singing apparatus; but the wings, instead of being arranged in the form of a high pitched roof, are laid flat upon the back. Some of them possess ocelli, whilst others are destitute of those organs. The hinder wings are very long, and folded up in such a manner that they project beyond the wing-cases, in the form of a pair of tapering tails; the abdomen is also furnished, in both sexes, with a pair of pilose, bristle-shaped, caudal appendages, and in the female with a long, slender ovipositor, composed of two filaments, laid side by side, and somewhat thickened at the tip. The tarsi are three-jointed.

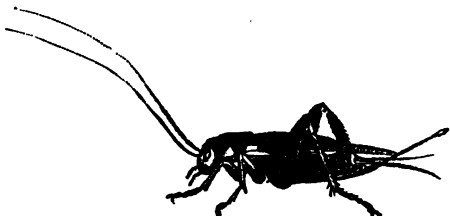


Fig. 202.—Cricket (*Acheta domestica*).

The common House-cricket is too well known to need any particular description. During the colder months these insects always seek the habitations of man; when they establish themselves in the neighbourhood of the fire-place, in some room on the ground floor, generally preferring the kitchen, where their monotonous chirping may generally be heard in the winter evenings. In summer, however, they remove their quarters to the open air, taking up their abode apparently in the crevices of garden walls and similar situations. In fine summer evenings they sing most pertinaciously in the open air. Their food, when in the house, consists of crumbs of bread, and similar household refuse, which are generally to be found in abundance on the kitchen hearth. They are said to come into the houses about the end of August, probably to breed; as minute larvæ, not more than a line in length, may often be seen later in the autumn swarming about hearths inhabited by these insects.

It is singular that popular superstition should have attached an ominous significance to the chirping of this harmless little creature; and it is very ridiculous to find that even at the present day this sound is deemed an unfavourable omen in some parts of the country, whilst in others it is regarded as having a directly opposite meaning.

Apart from all superstitious feeling, however, opinions are greatly divided as to whether the fireside song of the cricket be pleasant or the reverse. Like the *Cicada* of

the ancients, the Cricket has found its poetical admirers; whilst by many its note is regarded with great dislike.

Another species is the Field-cricket (*Acheta campestris*), a timid animal which avoids the society of man, living all the year round in the burrows which it forms in sandy banks, amongst stones. This is much larger and louder than the domestic species, but is by no means so common, frequenting only hot, sandy districts. A still more remarkable insect, belonging to this tribe, is the Mole-Cricket (*Gryllotalpa vulgaris*, Fig. 178), which, both in its structure and habits, presents no inconsiderable resemblance to the Mole. Like that animal it is constantly engaged in burrowing in the earth; and to enable it to do this with facility its anterior limbs are converted into a pair of flat, fossorial organs, which are turned outwards in exactly the same manner as the hand of the Mole. It is a British insect, but very local in its distribution. In its passage through the earth it does great injury to the roots of plants, but is said to live quite as much upon animal as upon vegetable food. The female forms a chamber of considerable size for the reception of her eggs, communicating with the surface of the ground by narrow winding passages, all neatly made and perfectly smooth. The number of eggs appears to be from two to four hundred. The young ones remain in society until after their first moult; when they disperse, and form separate burrows for themselves.

The habits of the three British species of Crickets form the subject of three of the admirable letters of Gilbert White. A species of Mole Cricket, inhabiting the West Indies, has frequently committed great ravages upon the young sugar-canes in those islands.

The *Cursorial Orthoptera* may be divided into four tribes, of which one is composed of exclusively herbivorous animals, whilst the others are either predaceous, or adapted to subsist upon a miscellaneous diet.

The herbivorous tribe, *Phasmina*, is composed of some singular insects, to which, from their close resemblance to vegetable productions, the names of *Walking sticks* and *Walking leaves* are commonly given. They are distinguished by having the head exserted, all the legs adapted for walking, the caudal appendages usually small and not jointed, and the hinder wings not folded transversely in the middle. Ocelli are sometimes present, sometimes wanting. The tarsi are composed of five joints, clothed beneath with a membranous cushion, which gives the creatures a firm hold of the branches and leaves of the trees on which they live, and furnished with a large pulvillus between the claws. The wings are sometimes present, sometimes entirely wanting; and in some species the male is winged and the female apterous. In the *Walking sticks* (*Phasmida*, Fig. 203), the body is much elongated, cylindrical, and usually of a dingy brownish colour, so as exactly to resemble the dried twig of a tree. The wing-cases, when present, are very much shorter than the wings; and as they would be quite insufficient for the protection of those organs when folded,

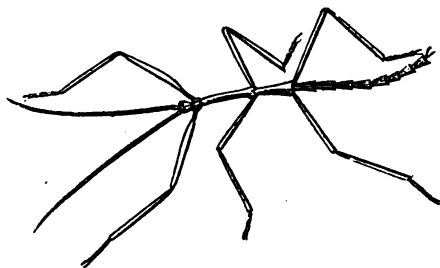


Fig. 203.—*Bacteria Fragilis*.

this is provided for in another way, the outer margin of the wings forming a firm plate, under which the membranous portions are entirely concealed during repose.

The Walking leaves (*Phylliidae*, Fig. 204) are still more remarkable in their appearance. In these the body is very flat and thin, and the wings form large, leaf-like organs, covering nearly the whole abdomen, and furnished with irregularly reticulated nervures, which give them exactly the aspect of a leaf. This leafy structure pervades



Fig. 204.—*Phyllium Siccifolium*.

the whole animal; the legs, especially the thighs, being always foliaceous. Some species are of a bright green colour, whilst others are of the brown of dead leaves; and the natives of the countries inhabited by these curious creatures generally inform Europeans that the insects are all green at first, but that as the leaves change colour they change also.

The *Phasmina* are found principally in warm climates, very few occurring in Europe. They are very slow in their movements, creeping about upon trees and shrubs, to which they often do considerable damage by devouring the young shoots. Some of the Stick insects are of large size, measuring at least seven or eight inches in length.

The insects of the next tribe, the *Mantina*, are also principally inhabitants of hot climates, although a few species are common in the south of Europe. They are at once distinguished by the structure of their fore-legs, which are converted into powerful raptorial organs. The head is attached to the extremity of the prothorax; the face is triangular, the eyes large, and the ocelli three in number. The prothorax is elongated, forming a narrow neck, which, in the ordinary position of the animal, is carried upright. From the front of this segment the raptorial legs, which are very singular in their structure (see Fig. 179), take their rise. They are much stouter than the other legs; the coxæ are very long, and are united to the still longer thighs by a small trochanter. The tibiæ can be folded back, so as to come into close contact with the lower surface of the thighs, which are furnished with a distinct groove for their reception. Each side of this groove and the under side of the tibiæ are armed with numerous spines; those of the tibiæ being the smallest. Carrying these formidable weapons aloft in the air, the

Mantides move slowly along, and their whole attitude is so solemn that they are regarded with veneration by the inhabitants of all the countries in which they occur. In the south of Europe they are universally known by names indicative of the belief that their singular attitude is one of prayer; and according to ancient legends the *Mantis* has not always confined itself to silent devotion; for we are told that one of these insects, on being desired by St. Francis Xavier to sing the praises of God, immediately chanted a beautiful canticle. Another prevalent superstition regarding these creatures is, that if they be asked the way to a place they will immediately indicate the right road by holding one of their legs in that direction,—hence the name of *Soothsayers*, often applied to these insects, and the Greek word *Mantis* has the same signification. Unfortunately, however, all these amiable qualities are purely imaginary. The *Mantis* is one of the most voracious of its class, and only assumes this solemn and devout appearance for the beguilement of its unsuspecting victim. Slowly and cautiously it steals along by almost imperceptible degrees until within striking distance of its prey, when one of the fore-legs is instantly extended, and the struggling victim is soon mangled by the tremendous weapons of the destroyer. Nor are these organs employed solely in providing their owner with nourishment. These insects are excessively pugnacious, and two of them can scarcely come together without a combat, which generally has a fatal termination. Their manoeuvres, in such cases, resemble those of two horsemen in single combat. The Chinese amuse themselves with the combats of these insects, which they keep for this purpose in little bamboo cases.

The *Mantina* are sometimes adorned with brilliant colours; but their general tints are green and brownish gray. Some of them have a large eye-like spot on the wings. Their antennæ are usually rather long and thread-shaped; their tarsi are five-jointed; and the abdomen is furnished with a pair of short articulated caudal appendages. The eggs are laid by the female in rows, each egg inclosed in a separate cell. The entire mass of eggs is covered with a gummy substance, which afterwards hardens, forming a protective case. These cases, which are often of singular forms, are usually attached to the twigs of trees.

In the sixth tribe (the *Blattina*, or Cockroaches) all the legs are formed for running, as in the Walking sticks; but the head is more or less completely concealed beneath the anterior margin of the prothorax. The antennæ are very long and bristle-like, and composed of numerous joints. The ocelli are generally absent. The wings are frequently wanting, sometimes in the female only, but often in both sexes; the anterior wings or wing-cases, are of a leathery texture, traversed by numerous reticulated veins. They lie flat on the body, and usually lap over each other at the apex during repose. The hinder wings fold up like a fan, excepting a rather broad piece of the anterior margin, which lies flat. The legs are rather long, generally stout, with the tibiae spinous and the tarsi five-jointed. The body is usually flat, and somewhat ovate, and the abdomen is furnished with a pair of jointed caudal appendages.

The common Cockroach, or Black-beetle as it is commonly called (*Blatta orientalis*, Fig. 205), which often swarms to such an extent in houses as to be a complete nuisance, may serve as a well-known example of this tribe; although in it the wings, which in many species attain at least the length and breadth of the abdomen, are reduced to a very small size in the males, whilst in the females they are quite rudimentary. These insects, although now so common all over Europe, are supposed to have been originally natives of India, and to have been gradually carried westward by the progress of commerce. This and another species, the *Blatta Americana*, are very

common on board ships, where they find a plentiful nourishment amongst the merchandize; and on shore they are usually most abundant in seaport towns.

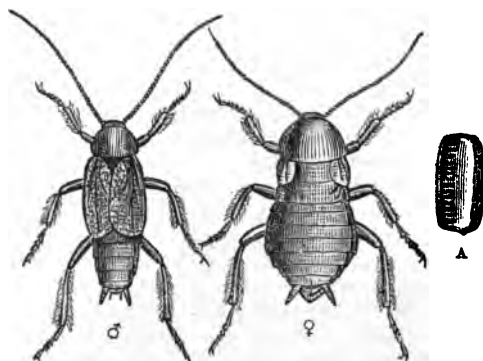


Fig. 205.—Common Cockroach, or Black-beetle (*Blatta orientalis*).
♂, male; ♀, female; A, egg-case.

They are all nocturnal in their habits, concealing themselves in dark holes during the day, but coming out of their hiding-places when the lights are extinguished. On the introduction of a light into the scene of their nocturnal prowlings they may be seen scuttling away in great disorder towards the nearest place of concealment; and from this habit, no doubt, the ancients, who were well acquainted with Cockroaches, denominated them *lucifuga*.

The common Cockroach, and some allied species, appear to have the faculty of devouring every thing that comes in their way; whether of an animal or vegetable nature; and when they occur in great numbers, the damage they do to provisions and many other articles is excessive. They also usually communicate a disagreeable smell to objects which they have touched, so that they often spoil more than they actually consume. A large species (*Blatta gigantea*), common in the West Indies, is there known by the name of the *Drummer*, from its curious habit of making a knocking noise during the night. This noise is frequently kept up all night, the insects alternately answering each other, to the great annoyance of those living in the house thus infested.

This species is also said occasionally to attack people when asleep; and, as though its other habits were not sufficient to create a prejudice against it, it sometimes devours the extremities of the dead.

The most remarkable circumstance, in the history of these insects, is the mode in which their eggs are laid. Instead of emerging singly from the abdomen of the female, they are inclosed in a horny case (Fig. 205 A), which is often half as large as the abdomen of the parent. Within this the eggs are ranged in two rows, separated by a partition which runs down the middle of the case; each egg is also separated from its neighbours by a similar but smaller partition. Along one side of the case there is a slit, furnished with a pair of toothed plates, which fit closely together, and which are further secured by the mother with a strong coating of a sort of cement, which also serves for the attachment of the egg-case to any spot which she may select for this purpose. When the larvæ are hatched they speedily emit a fluid from their mouths, which softens the cement, and enables them to escape from their temporary prison. As might be expected, the female has some difficulty in getting rid of this composite offspring, and the insects may often be seen running about with half the egg-case protruding from the apex of the abdomen. Indeed the birth is said to occupy for a week

to a fortnight in different species. By Dr. Leach the *Blattina* were raised to the rank of a distinct order, under the name of *Dictyoptera*.

This was also the case with the next and last tribe, the *Forficulina* or Earwigs, which constitute the order *Dermaptera* of Leach, and which Mr. Westwood, who also regards them as forming a distinct order, has denominated *Euplexoptera*. The latter name refers to the most striking character of these insects, viz., the structure of the hinder wings, which are exceedingly beautiful. In these the radiating nervures, instead of finding their common centre at the base of the wing, as is the case in most *Orthoptera*, spring from the extremity of a broad leathery piece, which occupies about a third of the anterior margin. Other radiating nervures occupy the spaces between the principal nervures, but only run from the posterior margin to the middle of the wing; and the whole are united by a transverse nerve, which runs parallel to the posterior margin. By the assistance of these nervures the wing, which is of very delicate texture, folds up into exactly the shape of a closed fan; but as the wing-cases of the Earwig are very short, the wings can only be got under them by a very complicated transverse folding in two places—namely, at the apex of the leathery basal piece, and at a second point about the middle of the wing, where the nervures appear to be thickened. Even then the apex of the firmer part of the wing projects beyond the elytra. The *Forficulina* are further distinguished by having the head exserted, and destitute of ocelli, the tarsi composed of three joints, and the extremity of the abdomen furnished with a pair of forceps, which are often of large size.

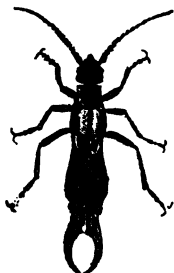


Fig. 206.—Forficula.

These insects appear to live principally upon vegetable substances, and as they often attack the petals of flowers, they are regarded as enemies by the gardener. They are nocturnal in their habits, creeping into crevices at the approach of day. It is this instinct that prompts them to take shelter in the flower-pots and other hollow objects usually placed as traps amongst the flowers which are subject to their ravages. It appears to be a common belief almost everywhere that the Earwig creeps into the ears of persons sleeping in the open air, passes thence into the brain, and causes death. Ridiculous as this fancy is, it appears to have furnished the name for the Earwig in almost all European languages. The female usually scoops out a hollow in the earth, in which she lays a small mass of eggs; these she watches over with great assiduity until they are hatched, when she continues to display the same affection for the new-born young.

ORDER VII.—NEUROPTERA.

General Characters.—The order *Neuroptera* includes a number of insects which present a considerable resemblance to the *Orthoptera* in their general organization, but which may usually be distinguished at the first glance by the structure of their wings. These are almost always four in number (Fig. 208), generally equal in size, and membranous in texture, traversed in various directions by longitudinal and transverse nervures, which are often excessively numerous. The wings are generally kept flat,

even during repose, although in some instances the posterior pair are folded. In the structure of the mouth some of them very closely resemble the preceding order; and



Fig. 206.—*Libellula cancellata*.

nearly all are furnished with distinct mandibles and maxillæ, although in one group these organs are very inconspicuous. The head is usually large, and distinctly separated from the body; the eyes are almost always of large size, and assisted by two or three ocelli; the antennæ are either thread-like or bristle-shaped organs. The segments of the thorax are distinctly recognisable, and the division between the thorax and abdomen is always distinct; although the latter is generally sessile, or attached to the last thoracic segment by its whole breadth. The legs are of moderate size, and the number of joints in the tarsi varies from two to five. The extremity of the abdomen is never armed with a multivalve ovipositor.

The metamorphosis (Fig. 187) of these insects approaches nearer completeness than that of the *Orthoptera*—the larvæ and pupæ generally exhibiting less resemblance to the perfect insects than in that order. The amount of resemblance between the different stages of these insects is, however, very variable in the different groups composing the order; so much so, in fact, as to have induced some naturalists to separate them into two, or even three orders. We may adopt these as our primary divisions or sub-orders.

Divisions.—In one of them, forming the *Dictyoptera* of Burmeister, the insects are active and voracious in all their stages; and although the appearance of the larvæ and pupæ rarely resembles that of the perfect insect very closely, yet this similarity is greater than in the other two sub-orders. In these the metamorphosis is much more complete. The pupa always presents a much closer resemblance to the perfect insect than the larva; and the intermediate stage of development is passed in a quiescent state, although the pupa acquires the power of motion a little before its emergence in the perfect form. In the *Planipennia* the wings are flat, membranous, generally equal in size, and naked; and the organs of the mouth are usually well developed; whilst in the *Irisoptera* the hinder wings are larger than the anterior pair, and folded in repose. The whole of the wings are more or less clothed with minute hairs; and the mouth is of very weak construction, and evidently incapable of biting.

SUB-ORDER I.—DICTYOPTERA.

Divisions.—Of the *Dictyoptera* some are aquatic in their habits in the larvæ state, whilst others are always aerial. Of the latter, which make the nearest approach to the *Orthoptera*, the *Termitidæ*, or White Ants, are the most important. These insects live in vast communities, principally in the hotter regions of the earth, where they do incredible damage by devouring everything that comes in their way. Even

wood is incapable of resisting their ravages; for they will gnaw away the interior of beams and articles of furniture, leaving a thin shell to conceal their operations, so that the mischief is not discovered, until, from its weakness, the object falls to pieces on being touched.

Considerable uncertainty still appears to exist as to the real constitution of the societies of these insects. According to Latreille they consist of five classes of individuals. Of these, two are undoubtedly males and females, which at first are exactly similar, and furnished with four nearly equal wings.

After impregnation the abdomen of the female increases vastly in size, from the immense number of eggs contained, which are so numerous that it is said as many as eighty thousand are sometimes laid by one female in the course of twenty-four hours.

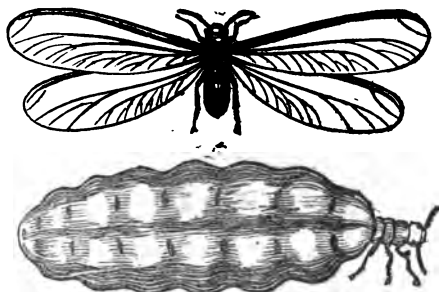


Fig. 209.—Queen in the winged state, and filled with eggs.

The great bulk of the community is composed of apterous individuals, supposed to be larvae, which closely resemble the winged insects, but are destitute of eyes and ocelli. These are the workers, and upon them all the labour of the community devolves. Other apterous individuals, apparently pupæ, resemble the workers, but have four tubercular wing-cases on the thorax; whilst others, distinguished by the large size of their jaws (Fig. 210), and which appear to be neuters, are called *Soldiers*; their office, apparently, being the defence of the community against the assaults of enemies.



Fig. 210.—White Ant Soldier.

The habitations raised by these diminutive creatures are amongst the most surprising of insect edifices. They are usually built upon the ground, but sometimes amongst the branches of trees, whence they communicate with the ground by a long gallery, twining round the branches and trunk of the tree. Those built on the ground are of various forms, two of which are represented in the annexed wood-cut (Fig. 211); but the most usual shape is an irregular cone. These nests are frequently as much as ten or twelve feet in height, built of earthy particles, which the workers masticate, and then apply to this purpose. It speedily dries, and becomes very hard. The nest is divided internally into numerous chambers and galleries (Fig. 212), in one of which the impregnated female or queen is

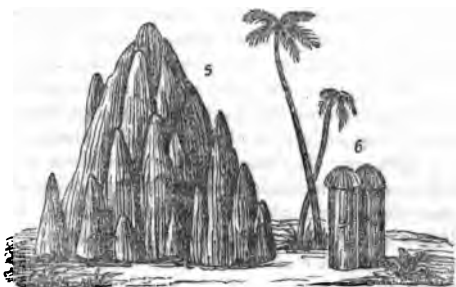


Fig. 211.—Nests of White Ants.
5, *Termes fatalis*; 6, *Termes atrox*.

imprisoned, waited upon obsequiously by a numerous train of attendants, whose

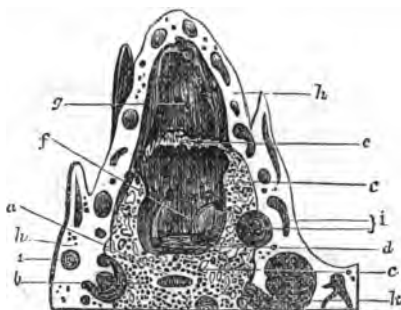


Fig. 212.—Section of Nest of *Termes fatalis*.

a, royal chamber; *b*, apartments of royal attendants; *c*, nurseries and magazines; *d*, lower roof; *e*, upper roof; *f*, bridges; *g*, dome of nest; *h*, walls of dome, penetrated by passages *i*; *k*, underground passage.

apartments are in the immediate vicinity of the royal chamber. These attendants carry off the eggs, as soon as laid, into separate chambers or nurseries, where the young produced from them are tended with the greatest care by the workers. The interior of the nest forms a large dome, with thick wall, within which there are usually two or three roofs; the walls are perforated by passages leading from the bottom of the nest to the magazines and nurseries placed in its sides, which also frequently communicate with the ground floor by small earthen bridges. Other species, although

differing in details, follow the same general principles in the construction of their nests.

The antennæ of the *Termitidæ* are thread-shaped, and composed of about twenty joints; the eyes are rather small, but prominent, and the ocelli two in number. The structure of the mouth presents a close resemblance to that of the *Orthoptera*. The thoracic segments are distinct, the wings large, equal in size, membranous, and traversed by numerous branched nervures, and the legs are short, and furnished with four-jointed tarsi. The abdomen is furnished with a pair of minute caudal appendages. Only two or three species of these insects are found in Europe; and although these can make no pretensions to rival their tropical brethren in destructiveness, yet the ravages of one species have produced considerable consternation of late years in the city of Rochelle, in France.

Nearly allied to these are the *Psocidæ*, a family of minute insects, distinguished by having their labial palpi very minute, their tarsi composed of two or three joints, and the hind wings smaller than the anterior pair. Several species of insects belonging to this family are common in this country, and one species, the *Atropos pulsatorius* (Fig. 213), which appears never to acquire wings, is often met with in abundance in badly kept collections of insects, dried plants, &c., to which it is very injurious. The name of *pulsatorius*, given to this insect, refers to its power of producing a sound like the ticking of a watch, whence it has often been denominated the *death-watch*. The generic name *Atropos* also hints at this popular superstition.



Fig. 213.—*Atropos pulsatorius*.

The remainder of the *Dictyoptera* pass through their preparatory states in the water; and it is not until the perfect insect is about to emerge from the skin of the pupa that the latter leaves its native element. It then creeps out of the water, either on to the stones on the brink, or up the stems and leaves of aquatic plants; and from this position the imago is able to spring at once into the air, without any danger of being drowned in its native element.

In the *Perlidæ*, which approach most closely in their structure to the preceding

families, the antennæ are filiform, as in those insects, but the posterior wings are considerably larger than the anterior, beneath which they are folded in repose, and the abdomen is furnished with a pair of rather long, jointed caudal appendages, which are also present in the larva. The tarsi are composed of three joints; the organs of the mouth are of a softish texture, the mandibles usually rudimentary, and the palpi both of the maxillæ and labium well developed.

The larva closely resembles the perfect insect, and is found in plenty in lakes, ponds, and rivers, on the borders of which the insects themselves may also be met with in abundance. The well-known *Stone-fly* of the angler, which is said to be an excellent bait for Trout, is a species of this family (*Perla bicaudata*). They are carnivorous insects, but sluggish in their movements. The respiration of the larva is effected by means of gills attached either to the thorax or to the abdomen, the form of which varies greatly in different species. In one genus (*Pteronarcys*) which inhabits North America, these branchial organs are persistent in the perfect state.

This sub-order includes two other groups, distinguished from the preceding, and indeed from all the other *Neuroptera*, by their small awl-shaped antennæ. They form the section *Subulicornes* of Latreille. The *Ephemeridæ* are distinguished by the small size of their hinder wings, the rudimentary condition of the organs of the mouth, and the long jointed bristles with which the tail is furnished. The antennæ are composed of only three joints; the eyes are usually large, and the ocelli three in number. These insects are well-known to the angler as May-flies. They are also called Day-flies, from the shortness of their existence in the perfect state; and the generic name of the typical group also refers to their *ephemeral* life. Their transformations have already been figured (page 342).



Fig. 214.—May-fly (*Ephemera*).

Both larvæ and pupæ present a considerable resemblance to the perfect insect; but the entire period of the preparatory stages is passed in the water, and the insects are then furnished with a row of very curious gill-laminæ along each side of the abdomen. During this period the larvæ and pupæ make themselves little burrows in the sides of the pond or stream in which they live, and these burrows have two openings; so that if the insect enters by one it can pass out by the other without the necessity of turning round in its narrow domicile. The caudal filaments are present in the larva, but much shorter than in the imago. On arriving at maturity the pupæ come out of the water, when the perfect insect emerges from its case, and takes to flight. It is still, however, inclosed in a very delicate pellicle, to get rid of which it soon attaches itself by its claws to any object that may be at hand, and after a few struggles leaves this encumbrance behind it, and flies away. After this last change the insect exhibits its brightest colours, and the tails grow to twice their previous length. The emergence of these insects from the water appears always to take place in the evening; and as the whole of the *Ephemera* in a river appear to arrive at maturity at the same period, they generally make their appearance in such countless swarms, for two or three evenings, that the effect produced by one species with white wings has been compared to a heavy fall of snow. By the next morning the majority of these insects are found lying dead upon the shore in heaps.

The occurrence of these swarms of May-flies has been observed in different parts of Europe, in Holland, France, and Switzerland; and it appears that the species found in each of these localities is distinct from the rest. In Switzerland, indeed, the swarms of two species are on record, one inhabiting the Lake of Geneva, and the other the Rhine near Basle. Our common species, the *Ephemera vulgata* (Fig. 214), also occurs in profusion for a few days in the rivers frequented by it, but not by any means to the same extent as the continental species just referred to. This and several other species of the family are favourite baits for Trout.

The *Libellulids* (Fig. 208) are characterized by their four large, nearly equal, reticulated wings, by the powerful structure of their mouths, and the shortness of the caudal appendages, which moreover are not jointed. The antennae are composed of from five to eight joints; the eyes are very large, generally meeting on the top of the head, which also bears three ocelli.

These are exceedingly elegant but voracious insects, which may be seen in fine summer weather hawking about over the surface of ponds and rivers in search of insect prey. They are well known in this country as Dragon-flies; the French call them "Damoiselles," probably in allusion to the elegance of their forms and the grace of their movements. The vulgar English name of Horse-stingers is peculiarly inappropriate, as these insects possess no means of annoying either horses or any other of the larger animals.

The larvæ and pupæ of the *Libellulids* inhabit the water, from which the pupa emerges when the perfect insect is ready to commence its aerial existence. The empty pupa skin may often be seen attached to aquatic plants. The structure of the lower

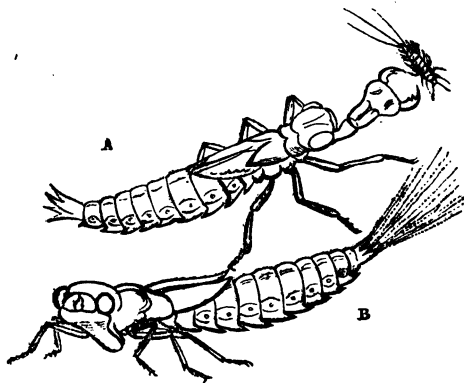


Fig. 215.—A, the pupa with its mask; B, the same with the mask closed, and discharging a current of water from the anus.

lip, in the preparatory states of these insects, is very singular; it has been denominated a *mask* by many authors. It consists of two principal pieces (Fig. 215), one of which is articulated to the head, whilst the second is attached to its extremity. At the apex of this second piece two jaw-like organs are articulated. In repose this lip is folded beneath the head, but can be immediately extended to a considerable distance in front of the head, so as to seize any minute insects or small fishes that may pass before the

creature, which is very sluggish in its movements. The respiration of the larvæ of some of these insects is not effected by external branchiæ, but by the entrance of the water into the cavity of the body, where it comes in contact with the tracheæ, which deprive it of the air dissolved in it; it is then forcibly expelled through the opening by which it entered (Fig. 215). The resistance offered to the expulsion of this water also enables the larvæ to progress slowly. In some of the smaller species the larvæ is furnished with three narrow elongated caudal plates.

One of the most beautiful species inhabiting this country is the *Calepteryx virgo* (Fig. 216), which is not uncommon on the sides of rivers. It is of a deep steel-blue colour, and the wings have a large dark patch near the apex. Some exotic species allied to this have the abdomen at least six inches long.

Fig. 216.—*Calepteryx virgo*.

SUB-ORDER II.—PLANIPENNIA.

In this sub-order the wings are always nearly equal in size, reticulated, and generally laid flat upon the back when at rest, the posterior pair never folded. The labium is usually notched at the apex, but never deeply cleft, as in the preceding group. The antennæ are generally long, and either filiform or gradually tapering to the tip. The pupa is quiescent.

Divisions.—In one family, the *Sialidæ*, the larvæ is aquatic in its habits, and the perfect insect is always found in the neighbourhood of water. When mature the larvæ quits the water, and forms a cavity in the bank, where it passes the pupa stage. These insects are distinguished by the large size of the prothorax, which is nearly square.

The remaining families pass the whole of their lives in the air. Of these, one species, the curious *Myrmelontidæ*, or Ant-lions, are distinguished by their clavate antennæ, which are usually short; although in one genus these organs are elongated, and knobbed at the extremity, in the same way as those of Butterflies. The ocelli are wanting; the

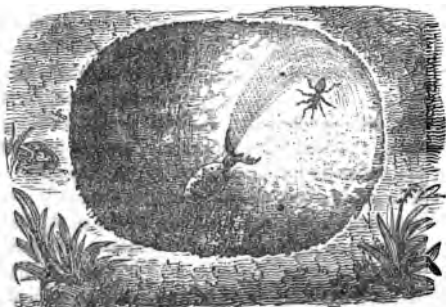
Fig. 217.—*Myrmelono*.

Fig. 218.—Pitfall of the Ant-lion.

labial palpi are very long, and the wings are large and finely reticulated, and during repose lie in a roof-like form upon the sides of the body (Fig. 217). Some of these insects, which are all exotic, are remarkable from the habits of their larvæ,—small, sluggish, oval creatures, furnished with a most formidable pair of jaws. These curious

little creatures excavate conical pits in the sandy places which they inhabit (Fig. 218), at the bottom of which they conceal themselves entirely, with the exception of the head and powerful jaws. Here they wait patiently until some prying ant or other insect unwarily strays into their domain, when the unfortunate intruder generally slips to the bottom of the pit, and is soon destroyed by the merciless jaws of the Antlion; but if the victim shows any intention of making his escape, a shower of sand thrown up by the latter soon arrests his progress, and generally brings him down to the fangs of the destroyer. It is entirely by sucking the juices of its victims that this voracious little creature exists; and when these are exhausted, the carcase is immediately thrown out of the pit by a sudden jerk of the jaws. The larvæ of other species appear to prowl about upon and under the surface of the ground without making pitfalls.

The *Hemerobiidæ*, which are closely allied to the preceding insects, are generally beautiful and delicate insects, with soft bodies, large, delicate, and finely reticulated wings, and long filiform antennæ. They possess no ocelli; but the eyes are large, prominent, and usually of a beautiful golden colour. The larvæ of these insects—of which several species are found in this country—are amongst the greatest enemies of the *Aphides*, which they suck by means of their curiously-constructed jaws. The eggs are laid in little bunches upon leaves, each egg being supported at the extremity of a long footstalk, which gives them a most singular appearance. Many of them are elegant creatures. They fly generally in the evening, and most of them emit a most disagreeable odour on being disturbed or touched. The pupa is inclosed in a cocoon.

The *Panorpidae* are characterised by the form of the head, which is prolonged below into a sort of rostrum, at the extremity of which the mouth is situated. They have long slender antennæ and three ocelli, and the extremity of the abdomen is often furnished with a curious forceps-like appendage, whence the commonest English species has obtained the name of the Scorpion-fly (Fig. 219). These insects are found commonly about hedges in damp situations; but little is known of their habits.



Fig. 219.—Scorpion-fly.
(*Panorpa*).

The two last families are distinguished from the preceding by the great length of the prothorax, which forms a slender neck, from which circumstance the few British species are denominated *snake-flies*. In the *Raphidiidæ* the fore-legs are formed for walking, the head bears three ocelli, and the antennæ are long and slender; the abdomen of the female is furnished with a long ovipositor. The larvæ are said to live under the bark of trees; and the insects are generally found in woods. This family includes several British species; but none of the next family, the *Mantispidae*, occur in Britain. These curious little insects are furnished with long raptorial fore-legs exactly like those of the Orthopterous *Mantidæ*, near which they have indeed been sometimes arranged. They have no ocelli, their antennæ are short, and the female has no ovipositor. They resemble the *Raphidiidæ* in their habits; and both families—especially the second—are apparently very predaceous.

SUB-ORDER III.—TRICHOPTERA.

The sub-order *Trichoptera*, including only the large tribe or family of *Phryganeidæ*, exhibits the most complete metamorphosis of any of the *Neuroptera*. The larvæ,

which are aquatic, in fact present almost as little resemblance to the imago as those of some metabolous insects. They are long, softish grubs, furnished with six feet, and with a horny head armed with jaws, generally fitted for biting vegetable matters, although some appear to be carnivorous. To protect their soft bodies, which constitute a very favourite food with fishes, these larvæ always inclose themselves in cases formed of various materials; bits of straw and sticks, pebbles, and even small shells, being commonly employed in this manner. The materials of these curious cases are united by means of fine silken threads, spun like those of the Caterpillars of the *Lepidoptera*, from a spinneret situated on the labium. In increasing the size of its case to suit its growth, the larva is said to add only to the anterior end, cutting off a portion of the opposite extremity. When in motion, the larva pushes its head and the three thoracic segments, which are of a harder consistence than the rest of the body, out of its case (Fig. 220); and as the latter is but little, if at all, heavier than the water, the creature can readily drag it along behind it, thus keeping its abdomen always sheltered. It adheres stoutly to the inside of its dwelling by means of a pair of articulated caudal appendages, generally assisted by three tubercles on the first abdominal segment.

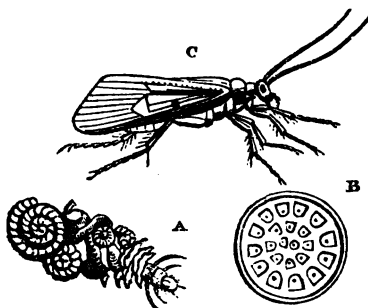


Fig. 220.—*Phryganea grandis*.
A, larva in its case; B, grating; C, imago.

Before passing to the pupa state, the larva fixes his case to some object in the water, and then closes up the two extremities with a silken grating, through which the water necessary for the respiration of the pupa can easily pass. The pupa is furnished with a large pair of hooked jaws, by means of which, when about to assume the perfect state, it bites through the grating of its prison, and thus sets itself free in the water. In this form the pupæ of some species swim freely through the water by means of their long hind legs, also creeping upon the other four limbs; these frequently rise to the surface of the water, and there undergo their final change, using their deserted skin as a sort of raft from which to rise into the air, whilst others generally creep up the stems of aquatic plants for the same purpose.

The perfect insects (*Phryganea grandis*, Fig. 220) have four wings, with branched nervures, of which the anterior pair are clothed with hairs; the posterior are folded in repose. The organs of the mouth, except the palpi, are rudimentary, and apparently quite unfit for use. The head is furnished with a pair of large eyes, and with three ocelli, and the antennæ are generally very long. Some species are so exactly like Moths, that they have often been supposed to belong to the *Lepidopterous* order; and, in fact, these insects may be considered to form a connecting link between the *Neuroptera* and the *Lepidoptera*. The females have been observed to descend to the depth of a foot or more in water, in order to deposit their eggs.

Many species of these insects are found in Britain. The larvæ are well known to anglers under the names of Caddis-worms and Straw-worms. They are said to be excellent baits.

SUB-CLASS III.—METABOLA.

In this sub-class the metamorphosis is what is termed *complete*, the larva, pupa, and imago being generally very distinct in appearance. The larva is either a maggot, grub, or caterpillar, and the pupa is quiescent, and inclosed in a skin or case.

ORDER VIII.—APHANIPTERA.

This little order, which only includes the Fleas, of which one species, at any rate, is probably even too well known to many of our readers, presents an exceedingly remarkable structure, which has been a frequent source of perplexity to systematists. By many recent authors these insects have been arranged with the *Diptera*; but they differ from these so essentially in many of their characters that we have preferred retaining them as a separate and independent order.

The external covering of the Flea is a horny case, formed of very distinct segments (Fig. 221); those of the thorax being always disunited. Although apparently apterous,

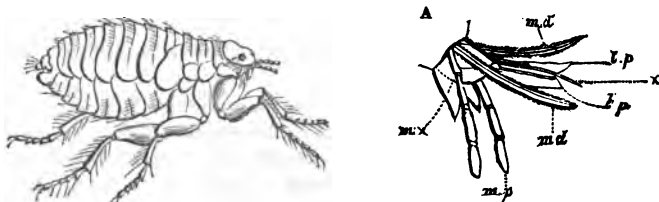


Fig. 221.—Flea (*Pulex irritans*).

A, mouth; x, supposed labrum; md, mandibles; mx, maxillæ; mp, maxillary palpi; lp, labial palpi.

the Flea has the rudiments of four wings, in the form of horny plates, on the sides of the meso- and metathoracic segments; the hinder pair of plates is the largest. The mouth, which, as is well known, is eminently suctorial, is of a very curious construction (Fig. 221 A), and the oral organs are so singularly formed, that their homologies have frequently puzzled entomologists. They consist of a pair of sword-shaped, finely serrated mandibles, which, with a sharp, needle-like organ (supposed to represent the labrum), appear to constitute the formidable offensive weapon with which the Fleas pierce the skin of their victims. These are sheathed by the three-jointed labial palpi. The labium and maxillæ are very small; but the maxillary palpi are long, and composed of four joints, and stand out from the head in such a manner as to have been generally mistaken for the antennæ. The latter organs are of minute size, and are generally concealed beneath a valve-like plate, on the sides of the head behind the eyes, although some species occasionally carry them exerted. The legs are strong, the hinder pair especially, by means of which these active little creatures execute their surprising leaps.

The larva of the Flea is a long, footless grub, furnished with a distinct horny head. They are hatched from eggs laid by the female, generally in the neighbourhood of animal matter. The eggs of the common species are usually laid in the cracks of floors and similar places. The larvæ are active, and when they attach themselves to dogs or other animals, they twist about freely amongst the hairs or

feathers, feeding upon minute particles of animal matter. In about twelve days the larvæ are full grown. They then inclose themselves in a little silky cocoon, and pass to the pupa state. In this condition the insect is quiescent, inclosed in a skin which fits over all parts of the body. The perfect insect emerges in about a fortnight. Most of the species of *Fleas*, or *Pulicidae*, are parasitic upon particular animals,—one of the largest being found upon the Mole.

A minute species, inhabiting the West Indies and South America, the Chigoe or Jigger (*Pulex penetrans*), is remarkable for the habit possessed by the female of inserting herself beneath the skin of the foot, generally under the nails. In this situation her abdomen swells to about the size of a small pea, in consequence of the development of eggs in the ovaries, occasioning great pain and irritation of the part, and if not extracted in time the eggs are said to be hatched within the wound, producing extensive ulceration, and sometimes even causing death. The feet of dogs are also attacked by this pest; and it is said that the unfortunate creatures may often be seen rolling about and nibbling their toes in a state of the greatest agony.

ORDER IX.—DIPTERA.

General Characters.—The order *Diptera*, as its name implies, is characterized by the possession of only a single pair of wings. These are attached to the mesothoracic segment; and the metathorax, instead of wings, bears a pair of small clubbed organs (*halteres*, Fig. 181), which appear to be the representatives of the posterior wings. Some entomologists, indeed, deny them this character, which they ascribe to a pair of small membranous organs, the *alulets*, attached to the base of the true wings; but this opinion appears to be founded in error. The halteres appear to be the most characteristic organs of the order, as they are present in those dipterous insects whose wings are wanting. The segments of the thorax are generally fused into a mass, their limits being indicated externally by more or less distinct furrows. The prothorax is always very small.

The head is generally of considerable size, and furnished with a pair of large compound eyes, which often occupy nearly its entire surface. It is usually attached to the thorax by a narrow neck, and the crown bears two or three ocelli. The structure of the mouth has already been described (p. 334, Fig. 176). The antennæ are always placed on the front of the head between the eyes. Their form is very variable. The legs are well developed, sometimes very long. The tarsi are composed of five joints, terminated by a pair of claws, and furnished with two or three soft pulvilli, by the assistance of which these creatures are enabled to walk with ease upon the smoothest surfaces, even in a perpendicular or reversed position.

The abdominal rings are distinct, and usually of a firmer texture than the rest of the body; some of the apical segments in the females are often converted into a telescope-like ovipositor. The stomach is furnished with a small sucking stomach, which communicates with it by a very slender tube. At the base of the abdomen are two air bladders, often of considerable size; the position of which is sometimes indicated by the semi-transparent appearance of that part of the body.

The larvæ of the *Diptera* are footless grubs or maggots, sometimes destitute of a distinct head. The stigmata are usually only two in number, and placed at the posterior extremity of the body. In some cases the larva, on reaching maturity, casts its skin, and changes to a free quiescent pupa; whilst in many species this transformation

takes place within the skin of the larva, which then hardens, and forms a case for the protection of the sleeping inmate. This constitutes what is termed a coarctate pupa.

Divisions.—The enormous number of species included in this, which is certainly one of the largest, if not the largest, of the orders of insects, has given rise to a corresponding multiplicity of families and other minor groups. In the following pages we shall refer, as briefly as possible, to the principal of these.

The order is divided into three sub-orders. The first consists of parasitic and often wingless insects, which have the head usually immersed in the thorax, and the

claws denticulated. These are called *Pupipara*, from the singular circumstance that the larvæ are nourished within the body of the mother, and not excluded until they have attained the pupa state. Of the other two sub-orders, which are generally oviparous, although a few bring forth living larvæ, one, the *Brachycera*, is distinguished by having the antennæ short, and composed, apparently, only of three joints, with the

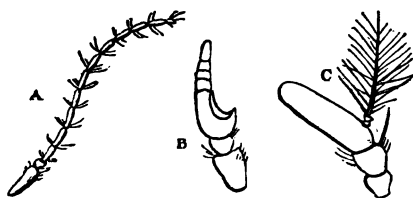


Fig. 222.—Antennæ of Diptera.
A, *Tipula*; B, *Tabanus*; C, *Musca*.

last joint generally furnished with a bristle (Fig. 222 C); whilst in the *Nemocera*, forming the third sub-order, the antennæ (Fig. 222 A) are always composed of more than six joints, filiform, and usually feathered. In the *Brachycera*, the palpi also consist of only one or two joints; whilst in the *Nemocera*, these organs are composed of four or five articulations.

SUB-ORDER I.—PUPIPARA.

General Characters.—In addition to the characters already given, these insects differ from the other *Diptera* in the structure of the mouth, which is so singular that the analogies of its constituent parts are still doubtful. The lower part of the head is covered by a membranous plate, perforated by a minute orifice in front, where it is also furnished with a pair of minute coriaceous lobes, which have been regarded as modified palpi. Within this is a fleshy bent organ, terminated by a bristle-like sucker composed of three separate bristles: this can be pushed out of the aperture in the first-mentioned plate by the extension of their fleshy base, which is probably the labium, and in this manner they are employed in piercing the skin of the animals on which these insects are parasitic. Some of them are furnished with wings, whilst others are destitute of those organs. Their bodies and limbs are generally covered with bristles. The abdomen presents no indications of segments; so that in their appearance the apterous species often closely resemble spiders, from which circumstance the French call them “mouches araignées,” or spider flies.

Divisions.—They form two families, the *Hippoboscide*, or Forest-flies, in which the last joint of the tarsi is longest, and the *Nycteribiide*, or Bat-lice, in which the basal joint of those organs is longer than all the rest put together. In their habits both these families are very similar, living amongst the hairs and feathers of beasts and birds, where they run about with great agility, often progressing sideways. They live

by sucking the blood of their victims. Young birds appear to be especially the objects of their attacks, and are frequently driven completely to distraction by their tormentors. The species of *Hippoboscidae* live upon different mammals and birds; the *Hippobosca equina*, or Forest-fly, is very troublesome to horses; and the *Melophagus ovinus*, which is apterous, is well known as the Sheep-tick. The *Nycteribiidae* confine their attacks to bats.

SUB-ORDER II.—BRACHYCERA.

General Characters.—In the *Brachycera* the antennæ are always short, composed apparently of only three joints, the last joint being sometimes articulated at its extremity (Fig. 222 B), sometimes entire, and generally furnished with a long, sometimes jointed, bristle. The palpi consists of one or two joints; the body is generally broad, and the head usually as wide as the thorax.

Divisions.—As this sub-order includes by far the greater portion of the almost innumerable hosts of Dipterous insects, the number of families and sub-families of which it is composed is, as might be expected, exceedingly great. They may, however, be divided into seven principal groups (families or tribes), and to these we must confine our attention.

In the *Oestridæ*, the proboscis is usually imperceptible, or, when present, very small; the antennæ are very short, and the last joint is furnished with a long bristle; the alulets are large, and entirely conceal the halteres. Although most of these insects, from the obsolete nature of their mouths, are probably incapable of taking nourishment when in their perfect state, they are nevertheless to be regarded amongst the greatest pests to cattle in their larva state. During this period of their existence they are all parasitic upon different species of herbivorous *Mammalia*, some of them living in the skin, and others in the internal cavities of their hosts. Of the former, the best known is the *Oestrus bovis*, the larvæ of which reside in the large tumours on the backs of cattle, known to the farmer under the names of *worms* and *worbles*. Of the internal parasites, some (such as the *Cephalemyia Ovis*) live in the frontal sinuses of sheep and deer, the parent laying her eggs in the nostrils, whence the young larva creeps up into its destined abode; whilst others, of which the *Gasterophilus equi* (Fig. 223) is an example, inhabit the intestines of their victims. The eggs of the latter species are laid upon the skin of the horse in such positions as are easily reached with his tongue, so that in licking himself he is instrumental in conveying his foes into his intestines. The internal larvæ are furnished with rings of bristles to enable them to retain their position; but they all quit their abode when mature, and undergo their last transformations in the earth, or in dung. The pupa is inclosed in the dried larva-skin.

The two next families are distinguished by having only two bristles in the proboscis. The *Muscidæ* are further characterised by having the proboscis membranous and completely retractile, terminated by two large lobes (Fig. 224); the antennæ are short, three-jointed, with a long and often pilose bristle attached to the third joint. This family includes an enormous number of species, presenting an almost infinite variety of habit. An excellent example (the common Fly, *Musca domestica*) occurs during the



Fig. 223.
Gasterophilus equi, and larva.

summer in even too great abundance in our houses; and many others, almost equally common, may be met with at all seasons of the year. In the larva condition, some of them, including the common Fly, live in dung; others, such as the common Flesh Fly (*Sarcophaga carnaria*) feed upon animal substances. Some of these, of which the common Cheese-hopper (*Piophilæ casei*, Fig. 225) is an example, possess a considerable power of leaping; their springs being effected by bending the body into a hoop, and then suddenly straightening it. Many of these larvæ, which feed upon animal substances in a state of decomposition, must be included amongst our greatest benefactors, as by removing, in a short space of time, matters which, if left, would corrupt and fill the atmosphere with noxious vapours, they prevent all the ill effects which those effluvia are known to produce upon animal life. So rapidly do they perform this business, that Linnaeus calculated that the progeny of three Flesh Flies would devour the carcase of a horse almost as quickly as a lion; and although there may be a little exaggeration in this statement,



Fig. 224.

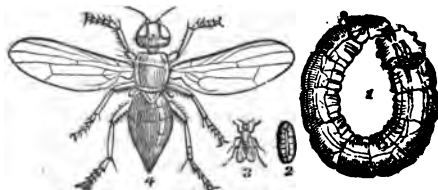


Fig. 225.

Fig. 224.—Head of *Musca*.

Fig. 225.—Cheese-hopper (*Piophilæ casei*). 1, Larva preparing to spring; 2, natural size of larva; 3, 4, Fly, natural size and magnified.

it is perhaps not very far from the truth. The larvæ of a great number of minute species are parasitic upon other insects; whilst those of many others feed upon plants, often causing great damage to various crops. Some of those which infest the leaves of plants form minute galleries or mines between the two membranes of the leaf by eating away the parenchyma.

The larvæ are soft footless grubs, frequently destitute of any distinct head, and generally of an elongated conical form, having the mouth, which is furnished with two retractile hooks, at the smaller extremity, and the single pair of stigmata at the larger. They are generally produced from eggs laid by the parent in the midst of the substances suited for their nourishment; but in some cases—as, for instance, in the Flesh-fly—the eggs are hatched within the body of the mother, and the insects make their first appearance in the larva form. The pupa is inclosed within the skin of the larva.

The habits of the perfect insects are as dissimilar as those of the larvæ. A great number inhabit flowers; others appear to feed upon almost every description of animal and vegetable matter; whilst some, such as the *Stomoxys*, attack man, and other animals, to suck their blood. They are generally dingy in their appearance, although some are adorned with brilliant colours. They exhibit a great variety of form. The most remarkable, perhaps, is that presented by the exotic genus *Diopsis*, in which the eyes are placed at the extremity of long stalks, with the antennæ close beside them.

The *Conopidae* are distinguished by having the proboscis long, elbowed, and always

exserted, with the palpi minute, and the antennæ furnished with a short bristle, which is frequently placed at the apex of the last joint. Most of these insects are elegantly variegated in their colours (Fig. 181). They may be found in great abundance during the summer, hovering upon their powerful wings over flowers in gardens and elsewhere. The larvæ are said to be parasitic in the interior of various species of Humble Bees.

In the three following families, or rather tribes—the *Brachystoma*, the *Notacantha*, and the *Tanystoma*—the proboscis usually contains either three or four bristles. In the *Brachystoma* the proboscis is very short and membranous, with the lip generally large, fleshy, and bilobed. The bristles are usually four in number; one group has only three of these organs. The antennæ consist of three joints, of which the last has a long bristle springing from its back. The abdomen of the male is usually bent round at the apex, and furnished with copulative appendages.

They are generally large flies, adorned with brilliant colours, which for the most part haunt flowers, living upon honey. A few, however, are predaceous in their habits. The larvæ are very various in their forms, and differ greatly in their mode of life. Many live in the earth; others in dung; whilst others are found upon plants amongst colonies of *Aphides*, which they destroy in great numbers, sucking their juices by means of a three-pointed spine.

The larvæ of the genus *Volucella* live parasitically in the nests of wasps and hornets, Those of the genus *Eristalis*, which inhabit dirty water and other foul liquids, are furnished with a singular telescopic tail, which they put to the surface of the water, and thus breathe, whilst all the rest of their bodies is immersed. This group is subdivided into four subordinate groups (families or sub-families),—the *Dolichopidæ*, the *Syrphidæ*, the *Therevidæ*, and the *Leptidæ*.

In the *Notacantha* the apparent last joint of the antennæ is composed of several articulations, which, however, are generally more or less amalgamated into an elongated mass, with the bristle, when present, springing from its apex. The back of the thorax is generally spined. The proboscis is short, and contains four bristles. The tarsi are furnished with three pulvilli. These insects are also frequently brilliantly coloured. They generally frequent flowers. The larvæ live in various situations; in the earth, in rotten wood, in dung, and in water.

The latter is the habitation of the larvæ of the typical genus *Stratiomys* (Fig. 226). They breathe, like the other aquatic Dipterous larvæ, through the tail, which is furnished with a circle of bristles to keep the water from rushing into the stigmata when these are applied to the surface. The pupa is inclosed in the larva skin.

The *Tanystoma* are generally distinguished by the great comparative length of their proboscis, which is often excessively long (Fig. 227), and rarely terminates in a very fleshy lip. The bristles are either four or six in number. The antennæ consist of three joints, usually terminated by a bristle. The transformations of these insects are

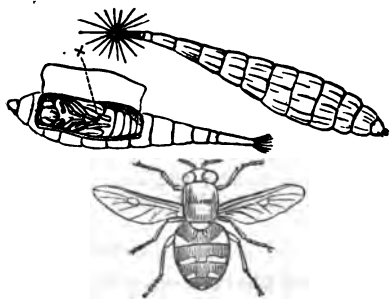


Fig. 226.—Larva, Pupa, and Imago of *Stratiomys Chamæleon*.

also different from those of the preceding groups. The larva-skin is always cast, on assuming the pupa state. The larvæ generally reside in the earth.

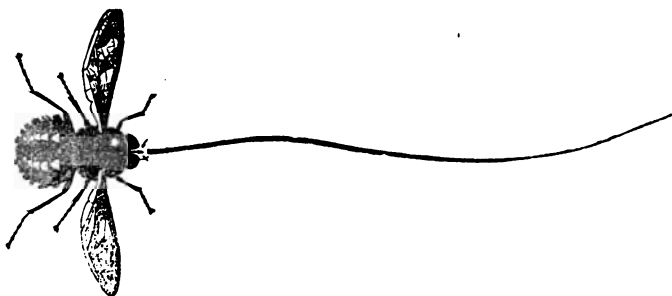


Fig. 227.—*Nemestrina longirostris*.

It is in the *Bombyliidæ* that the proboscis attains its greatest dimensions (see Fig. 227); these are generally hairy, bee-like flies, which suck their nourishment from flowers whilst hovering over them. In the *Anthracidæ*, the proboscis is short; and in the *Acroceridæ*, the organs of the mouth are sometimes entirely wanting. The *Empidæ*, the *Hybotidæ*, the *Asilidæ*, and the *Mydasidæ*, are all predaceous in their habits, as are also the *Tabanidæ*, the well-known *Gadflies*, or *Breeze-flies*, so troublesome to cattle and even to man, which are distinguished from the other *Brachycera* by the possession of six bristles in the mouth. In the *Tabani*, the last joint of the antennæ exhibits an articulated extremity (Fig. 228). They are amongst the largest



Fig. 228.—*Tabanus Bovinus*.

of Dipterous insects; and their rapacity and power of annoying their unfortunate victims are proportionably great.

SUB-ORDER III.—NEMOCERA.

General Characters.—The *Nemocera* are distinguished from all the other *Diptera* by the structure of their antennæ (Fig. 222 A), which are always rather long, thread-like, or formed of bead-like joints. The palpi are also long, composed of at least four or five joints; and both the palpi and antennæ are frequently plumose. The body is long and slender, and the legs often of extraordinary length.

Divisions.—Few of these insects present anything very attractive in their appearance. Their colours are almost always dingy, and their bodies soft; but, like many other creatures of the same description, they force themselves upon our notice by the injury they do either to our persons or our property; those of one of the two families into which they are divided being often exceedingly destructive to the vegetable productions of our gardens and fields, whilst those of the other are the most inveterate blood-suckers that ever tormented man or beast.

The *Tipulide* are in the former case. They have the proboscis very short, terminated by a pair of fleshy lips, and inclosing only two bristles. The common *Tipula*, or Daddy-long-legs, are well-known examples of this family; and their larvæ, which live in moist ground, often do great mischief, attacking the roots of grass in meadows, and sometimes denuding whole fields of their herbage. The larvæ of the *Cecidomyia* and their allies generally attack the young buds of trees, when they produce a sort of gall in which they come to maturity; whilst other species, such as the *Cecidomyia Tritici* and the *Cecidomyia destructor*, the dreaded Hessian fly of the United States (Fig. 229), generally attack the corn crops. The former of these larvæ feeds in the flower of the wheat, often rendering it abortive, whilst the other attacks the stem near

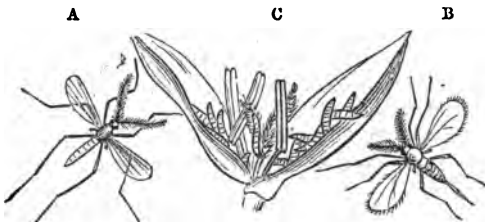


Fig. 229.—A, the Hessian Fly (*Cecidomyia destructor*); B, the Wheat Fly (*C. Tritici*); C, larvæ of *C. Tritici* feeding on wheat.

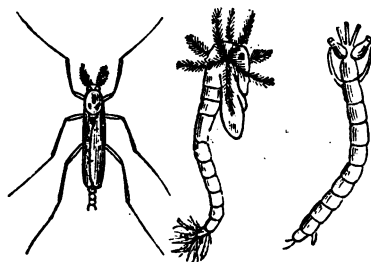


Fig. 230.—*Chironomus plumosus*, with its larva and pupa; all magnified.

the ground, and thus causes a still more wholesale destruction. The larvæ of *Chironomus* (Fig. 230) and its allies live in standing water; and the insects themselves closely resemble Gnats, both in appearance and in their habit of collecting in the evening in vast numbers, and dancing up and down in the air. The larvæ of *Chironomus plumosus* are of a blood-red colour, and are well known to anglers as blood-worms. The larvæ of a considerable number of species are found in fungi.

A few species depart somewhat from the generally peaceful character of the family, and suck blood with as much avidity as their neighbours the Gnats. Amongst these



Fig. 231.—Gnat (*Culex pipiens*). Female, natural size and magnified; head of male; and larva.

the species of *Simulium*, or Sand-flies, must be especially noticed, as their bite often gives rise to intensely painful swellings.

In the family of the *Culicidae*, or Gnats, which includes the pre-eminent blood-thirsty species, the proboscis is especially suited for their work of torment. It is often half the length of the insect, slender, slightly thickened at the tip, and incloses six long, sharp bristles. The palpi are often very long and beautifully feathered in the males; but in the females these organs are generally short.

These insects, their curious dances, and the very disagreeable effects of their bite, must be well-known to every one; but the Mosquitoes of warm climates, which are very nearly allied to our indigenous gnats, are still greater pests; and the inhabitants of India are compelled to protect themselves when asleep, by means of fine gauze curtains, from the attacks of these bloodthirsty little creatures.

The larvæ of the Gnats live in water, where they swim about with considerable agility, breathing air by placing the orifice of a long caudal tube at the surface of the water.

ORDER X.—LEPIDOPTERA.

General Characters.—In this last and highest order of the suctorial insects with a complete metamorphosis, we meet with creatures which must be ranked amongst the most elegant of the denizens of the air. The delicacy of the form of many species, the charming contrast of colour often exhibited in their wings, and the gem-like brilliancy of others, must always render them most attractive objects; and the attention of collectors has always been more directed to these insects than to those of any other order.

The structure of the mouth is almost always sufficient to distinguish a Lepidopterous insect from one belonging to any other order. The suctorial organ consists of a spirally rolled trunk (Fig. 232) attached to the lower part of the front of the head, and reposing, when coiled up, between the hairy labial palpi. The construction of this trunk has already been described. (See p. 333, Fig. 174).

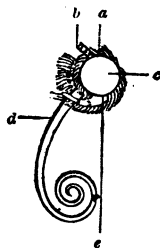


Fig. 232.

Head and trunk of Butterfly.
a, head; b, base of antennæ; c, eye; d, trunk; e, labial palpi.

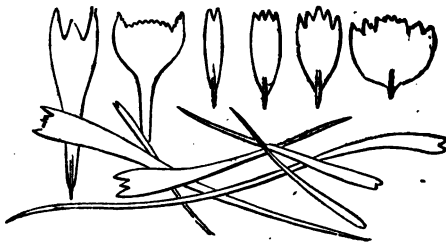


Fig. 233.

Scales from the wings of the Gnat-moth.

The wings are four in number, membranous, generally nearly flat, furnished with branching nervures. They are usually covered with minute scales, popularly called *feathers*, which are, in reality, only a peculiar form of the hairs with which the wings of most insects are furnished. In the *Lepidoptera* these are set very close together, usually more or less flattened, and laid over one another in the manner of tiles upon the roof of a house. Their form varies greatly in different species, and even on different parts of the wings of the same species (Fig. 233). It is entirely to these scales that the beautiful colours of the wings of these insects are due; and the metallic tints exhibited by many species are owing to the presence of very delicate striae upon the scales.

The thoracic segments are amalgamated into a more or less ovate mass, generally clothed with hair; the prothorax is very small. The legs are generally well developed; but in some species the anterior pair is rudimentary. The tibiae are spurred, and the tarsi usually composed of five joints.

The larvae of the *Lepidoptera* are well known as *Caterpillars*. They are generally of a more or less cylindrical form (see p. 349, Fig. 185), composed of thirteen segments, of which the anterior forms a horny head, furnished with jaws and antennae, and usually with groups of simple eyes.

☛ The jaws of the Caterpillar are usually very strong, and well adapted for biting the firm vegetable tissues upon which most of them feed.

The mouth is composed of the same parts as that of masticating insects. In addition to the usual pair of palpi, the labium bears a slender tubular organ, the *spinneret* (Fig. 234 i), which communicates with a pair of large internal glands, whose office it is to secrete the viscous substance necessary for the formation of the silky threads by means of which most Caterpillars secure themselves from falling, and with which many of them spin a cocoon in which to pass their pupa state.

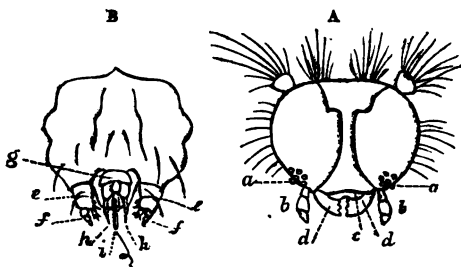


Fig. 234.—Head and Jaws of Caterpillars.

A, from above. B, from beneath. a, eyes; b, antennae; c, labium; d, mandibles; e, maxillae; f, maxillary palpi; g, labium; h, labial palpi; i, spinneret.

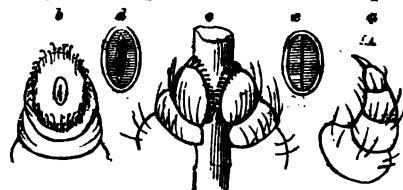


Fig. 235.—Leg and Pro-legs of Caterpillars.

a, thoracic leg; b, pro-leg; c, pro-legs grasping; d, e, spiracles open and closed.

in grasping any object upon which it may be resting or walking.

The duration of the larva state is very variable in these insects; many of them producing two broods annually, whilst others occupy two or three years in arriving at their perfect condition. In their larva state they are exceedingly voracious, often doing immense damage to vegetation. Most of them accordingly grow rapidly, and shed their skins several times before attaining maturity. When this period has arrived, the Caterpillar seeks some sheltered spot in which to undergo its change to the pupa form. Some species select the lower surface of leaves and branches for this purpose; others clefts and hollows in the bark of trees, walls, or palings; whilst others bury themselves in the earth. Those which remain in the air always suspend themselves in various ways by means of their silky secretion, and some inclose themselves completely in a silky cocoon. This is also done by some of those which conceal themselves in the

The three segments following the head, which correspond with the thoracic segments of the perfect insect, bear three pairs of soft, jointed legs, terminated by a single claw (Fig. 235 a), and, in addition to these, a variable number of the abdominal segments are also furnished with fleshy feet, called pro-legs (Fig. 235 b c), which are of great assistance to the creature

earth; but many of these only line their cavity with a sufficient quantity of silken threads to keep its walls from falling in upon them. The pupa is entirely inclosed in a horny case, in which the position of the wings and limbs is indicated externally only by lines and other elevations.

In their preparatory stages the *Lepidoptera* are exceedingly liable to be destroyed by numerous species of parasitic insects, which lay their eggs in the larva, which then continues to feed, and frequently even effects its transformation to the pupa state, without exhibiting any indications of the work of destruction which is going on within; and these parasites, assisted by the insectivorous birds, keep the numbers of Caterpillars within moderate limits. Without these checks, they would soon destroy the fruits of the labours of the gardener and the husbandman.



Fig. 236.—Tortoise-shell Butterfly just emerged from the chrysalis.

The perfect insect, on first emerging from the pupa case, usually has the wings soft and crumpled; and it is not until some little time after it has set itself free from its prison that its wings become sufficiently expanded to be available for flight. Many Butterflies, immediately before taking their first flight into the air, eject a red fluid from the anus, which, of course, forms a red spot wherever it falls; and this—when, as is sometimes the case, vast quantities of some species of Butterfly have simultaneously attained the perfect state in a particular district—has given rise to the stories of bloody rain.

Divisions.—The *Lepidoptera* are divided into two great groups or sub-orders, the *Heterocera*, and the *Rhopalocera*. In the former, the antennæ are of variable form, usually bristle-shaped, and frequently plumose, but very rarely clubbed. The hinder wings are furnished with a bristle on their anterior margin, which serves to keep the two wings of each side connected during flight, and the wings are never carried erect during repose. This group includes the numerous species of Moths. These are the *Nocturnal* and *Crepuscular Lepidoptera* (*Nocturna* and *Crepuscularia*) of many entomologists, so called from most of the species flying only by night or in the twilight.

In the *Rhopalocera*, or Butterflies, the antennæ are almost always terminated by a club; the wings are generally carried perfectly upright in repose, and the hinder pair are not furnished with bristles. These are the *Diurna* of some entomologists.

SUB-ORDER I.—HETEROCERA.

Divisions.—The *Heterocera* may be divided into eight groups or tribes, most of which include several families. In the first of these, the *Pterophorina*, or Plume-moths, the wings are divided into radiating finger-like segments, fringed on both sides with numerous delicate hairs, which give them the appearance of minute feathers. The antennæ are slender and bristle-like, the body slender, the legs long, and furnished with large spurs on the tibiae. All these insects have the habit of folding their wings like a fan when at rest. In some (*Ptero-*



Fig. 237.—*Alucita hexadactyla*.

phorus) the fore wings are but partially bifid, and the hind wings divided into three segments; whilst in others (*Alucita*, Fig. 237) the whole of the wings are composed of feather-like pieces. One genus arranged in this tribe has the wings entire. They are all of comparatively small size.

The second tribe, the *Tineina*, includes a multitude of minute insects, often of the most elegant forms, and adorned with colours as brilliant as those of the largest species of the order. They are distinguished by their filiform or bristle-shaped antennæ, which are very rarely plumose; but in many species they attain a considerable length, and are generally longer than the body; and by their narrow elongated wings, always terminated or edged by a long fringe. The palpi are usually of great length, and often of singular form.

The Caterpillars are provided with eight or ten pro-legs, in addition to the thoracic members. They inhabit the most various situations; and most of them either shelter themselves within the substance upon which they are feeding, or form themselves little cases, which they carry about with them. The majority feed upon green vegetable matter; many of these mine in the leaves and stems of plants, whilst others live upon the surface in small cases neatly made of a little piece of leaf. The most destructive species are those which live upon dry animal and vegetable matter, amongst which the well known Clothes-moths, and the Corn-moth (*Tinea granella*), which attacks corn in granaries, are the most noted. Two species of *Galleria* live in Bee-hives, to which they often do great damage.

The insects of the third tribe, the *Tortricina*, are distinguished by their short filiform antennæ, which are rarely feathered, and their broad triangular wings. The maxillary palpi are inconspicuous, the labial palpi elongated, and the body shorter and thicker than in the *Tineina*. The head is generally furnished with ocelli.

The larvæ possess sixteen feet; they live upon the leaves of trees and plants, which they generally roll up into a sort of tube (Fig. 238). Within this they feed in security, and here they also undergo their transformations. From this habit they have obtained their common name of Leaf-rollers, and their scientific name (*Tortrix*, *Tortricina*) has nearly the same meaning. When they occur in great numbers these insects are often exceedingly injurious in orchards and plantations.



Fig. 238.—Oak-leaf rolling Caterpillar (*Tortrix viridana*).

In the *Pyralidina* the antennæ are also rather short and filiform; those of the males are sometimes pectinated. The labial palpi are generally very long, and the maxillary palpi tolerably conspicuous. The wings are elongated and triangular, and the legs very long. The Caterpillars are usually furnished with fourteen feet, and covered with short hairs; they live upon leaves, and often, like the insects of the preceding groups, do much damage. The *Pyralis Vitis* (Fig. 239) is very destructive in wine countries, and other species are frequently injurious to trees in orchards. The larva of *Pyralis farinalis* lives upon flour and meal, and that of the *Aglossa pinguinalis* upon butter, grease, and similar substances.

In the *Geometrina* the antennæ of the females are filiform, but those of the males usually plumose; they are generally a little longer than the thorax. The wings are

large and broad, and the body slender. The name of this group is derived from the structure and habits of the Caterpillars, which are popularly known under the name of *loopers*. These only possess four pro-legs, placed quite at the hinder extremity of the body. In progression the Caterpillar holds by its thoracic feet, brings the hinder extremity close to these, bending the body into a loop, adheres by the pro-legs, and then again extends the fore part of the body for a fresh step. In this manner they proceed, apparently measuring the ground over which they travel, whence they have received the name of *geometricians*. Many of them present a close resemblance, in colour and texture, to a piece of dry twig, and they take advantage of this to deceive their enemies, adhering often for hours to one spot by their pro-legs, with the remainder of the body stretched out in a straight line. The Caterpillars of these insects are also very injurious to fruit trees,—that of the Magpie Moth (Fig. 240), which inhabits gooseberry bushes, often strips them almost entirely of their foliage.



Fig. 239.—*Pyralis Vitis*. 4, male at rest; 4a, female flying; 4b, caterpillar; 4c, eggs; 4d 4e, pupa.

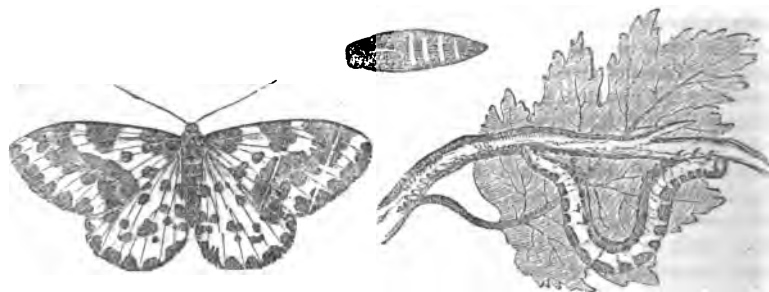


Fig. 240.—Magpie Moth (*Abraxas grossulariata*). Caterpillar, pupa, and imago.

The tribe of *Noctuina* includes a great number of Moths, of middling or large size, generally of dull colours, and strictly nocturnal in their habits. The antennæ are generally bristle-like, rarely pectinated or even notched, generally a little longer than the head and thorax; the palpi are short; the wings large, the anterior pair longer but narrower than the posterior, which are slightly folded in repose. The body is rather thick, and the legs are generally stout. The Caterpillars are generally naked, and furnished with sixteen feet. The pupæ are usually inclosed in a loose cocoon.

A few exceptions to the usual sombre colouring of the insects of this tribe are to be

met with, principally in species which are more diurnal in their habits than the rest. The *Catoxales* and *Triphaneæ* are distinguished by the bright red and orange colour of their posterior wings, and the *Plusiæ*, which often fly in the bright daylight, have the anterior wings adorned with metallic tints and markings.

The *Bombycinæ* have very short antennæ, generally plumose or pectinated, especially in the males. The wings are large, the posterior pair being broadest, and generally adorned with bright colours. The body is thick, and rather short; the legs are stout; and the spiral trunk is either altogether absent or very short. This tribe includes some of the largest species of the order; and its importance is greatly increased by the circumstance that the Silkworm Moth (*Bombyx mori*, Fig. 241) belongs to it. Of the commercial importance of this insect we may judge from the fact, that in the year 1850 nearly five million pounds of raw silk were imported into this country, besides a

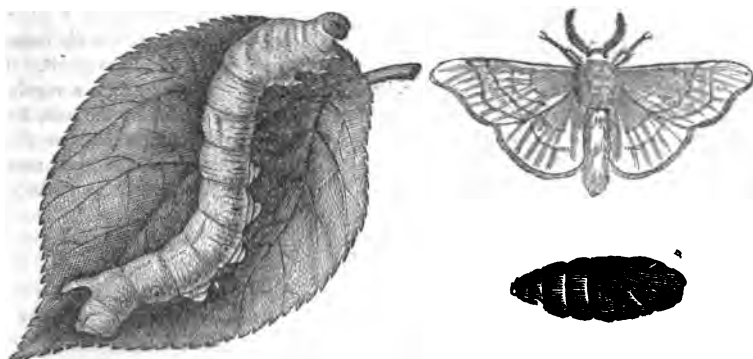


Fig. 241.—Silkworm, with its Pupa and Imago (*Bombyx mori*).

large quantity of manufactured silk. This important insect is a native of the north of China; and a great portion of our supplies of silk is still derived from that country. It was introduced into the south of Europe in the sixth century of the Christian era, when some of the eggs were brought to Constantinople, whence the insects have gradually spread into Italy and France—in both which countries the cultivation of the Silkworm is an important branch of industry. When the Silkworm is full grown it quits its food, and betakes itself to some convenient spot, where, after spinning a few threads in various directions, it suspends itself in the midst of them; and by continually twisting its body it gradually envelops itself in a thick silken cocoon. By spinning this carefully off, a delicate unbroken thread, sometimes exceeding 1100 feet in length, is obtained.

The *Bombyx Cynthia*, the Arrindy Silkworm of India, furnishes a silk which is said to possess astonishing durability. The Caterpillar feeds upon the Castor-oil plant (*Ricinus communis*), and has recently been introduced into the south of Europe, and into the French possessions in the north of Africa, with every probability of success. Several other species of these insects furnish silk.

The *Saturnia Prometheus* (Fig. 242), a fine North American species, nearly allied to the preceding, is remarkable for inclosing its cocoon within a leaf of the tree on which it habitually resides. Amongst British species, one of the most remarkable is the *Gastropacha quercifolia*, or Oak-lappet Moth (Fig. 243), in which the under wings project on each side of the upper ones when the insect is at rest, giving it a very singular aspect, not unlike a bunch of dead leaves, the insect itself being of a brown colour. Its mode of life, in the larva state, is not less curious. The larvæ live in a large community within a silken nest, which they weave for themselves; and on leaving it, in search of food, they form a regular procession, one taking the lead, followed by a certain number two abreast, then three, and so on, until they sometimes march in ranks of



Fig. 242.—*Saturnia Prometheus*, with its caterpillar, cocoon, and pupa.



Fig. 243.—Oak-lappet Moth (*Gastropacha quercifolia*).

ten or more. Hence they are called *processionary* Caterpillars, and the larvæ of several allied species have the same habit.

The Goat Moth (*Cossus ligniperda*), which is one of the largest British Lepidoptera, also belongs to this tribe; the larva feeds upon the wood of willows, to which it often does immense injury.

The *Psychide*, a family of singular small Moths, generally placed with this group, are remarkable from the circumstance that the larvæ form portable cases for their protection, similar to those constructed by the Caterpillars of many *Tineina*. In these they undergo their transformations; and the females of many of the species, which are often footless, grub-like creatures, do not leave this case, but are sought by the male whilst still inclosed. This circumstance has given rise to an impression that these insects produced fertile eggs without congress with the male; but this opinion proves to be unfounded in most cases; although, according to Siebold's observations, some of them exhibit phenomena of reproduction exactly analogous to those presented by the viviparous *Aphides* (see p. 348).

In the *Sphingina*, the last tribe of *Heterocerous Lepidoptera*, the antennæ are thickened in the middle or towards the end, but terminate in an acute point. They are generally prismatic in their form, and frequently pectinated or toothed internally. The wings are generally long and narrow, but firm, and adapted for powerful flight; and the trunk is almost always well developed; sometimes longer than the body. The name of *Sphinx*, applied to the typical genus of these insects, is derived from the habit of the larvæ of sitting with the head and fore part of the body raised in an attitude which, to a fanciful imagination, bears some resemblance to the Sphinx of the ancients. Most of these insects fly in the twilight; but some are to be found hovering over flowers in the brightest sunshine, extracting the nectar by means of their long trunks. They are generally insects of considerable size, and the appearance of the larger species is well shown in the annexed figure (Fig. 244) of the Elephant-Hawk-Moth, *Deilephila Elpenor*. Perhaps the most remarkable species of this tribe is the Death's-head Moth (*Acherontia Atropos*), a large species, variegated with dark brown and yellow, and which bears upon the back of the thorax a deep orange mark, presenting no inconsiderable resemblance to the front of a human skull. Hence this insect, whenever it has occurred in sufficient plenty to attract general attention, has always been regarded as ominous of pestilence,—a feeling, probably, not diminished by its power of emitting a plaintive squeak when disturbed. The larva is very partial to the potato plant, and the pupæ are often turned up in digging potato grounds. The moth, which has a very short trunk, is a great enemy to bees, invading their hive, and feeding upon their honey. It is supposed to frighten the bees by the squeaking noise above referred to; for though it possesses no weapons, and the bees are well armed, they never appear to attack the intruder.

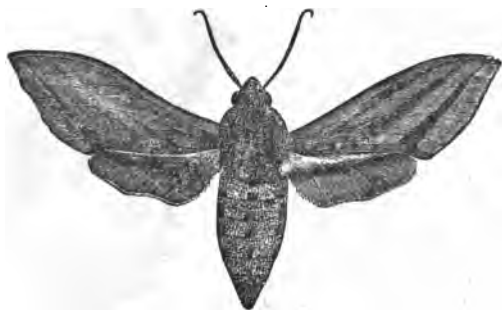


Fig. 244.—Elephant Hawk-Moth (*Deilephila Elpenor*).

A considerable group of small insects, belonging to this tribe, have transparent membranous wings, only partially clothed with scales; amongst these one, the *Sesia*

tipuliformis, is very common in gardens, where its caterpillars feed in the interior of the twigs of the currant and gooseberry bushes. The transition to the *Rhopalocera* is effected through the *Castnidea* and *Uraniida*, two groups of butterfly-like insects, of which the latter, at all events, has frequently been placed in the following sub-order.

SUB-ORDER II.—RHOPALOCERA.

This sub-order, including the numerous beautiful species of Butterflies, which probably, as a group, may be regarded as the most charming of insects, forms only a single



Fig. 245.—*Danais plexippa*.

tribe, which, however, is divided into numerous families and sub-families. They are all diurnal in their habits, fluttering about from flower to flower in the hottest sunshine, and nearly all of them carry their wings upright over their backs in repose (Fig. 245). It is in hot climates that the largest and most magnificent species abound. Under the burning rays of the tropical sun numerous brilliantly metallic species sport like living gems; and even those not adorned with metallic tints exhibit an elegance and variety of colouring which is perhaps not surpassed by any other productions of nature.

Beautiful as these creatures are, however, their structure and habits exhibit so little diversity that we may pass them over with but a few words. The

caterpillars, which feed upon the leaves of various plants, are almost always furnished with sixteen feet. They are as voracious as the larvæ of the Moths; some of them, such as those of the Cabbage Butterflies (*Pontia brassicae* and *Rapa*), often doing great injury in gardens. The Caterpillars of the family *Papilionida*, of which the only British species has already been figured, with its transformations (Fig. 185), are furnished with a curious forked retractile process on the back of the neck, which has been supposed to be employed in frightening away insect foes. The pupæ, ordinarily known as *Chrysalides*, are usually more or less angular; these angles often becoming so prominent as to take the form of



Fig. 246.—Peacock Butterfly (*Vanessa Io*).

spines. Unlike the pupæ of many Moths, they are not inclosed within a cocoon, but either simply suspended by the tail, or furnished with the additional security of a little silken band round the middle. One of the most beautiful of our native species is the Peacock Butterfly (*Vanessa Io*, Fig. 246), the wings of which are adorned with splendid eye-like spots. Its Caterpillar feeds upon nettles. Several other charming British

species belong to the same genus with the Peacock Butterfly. Of these the commonest are the Tortoiseshell (*V. Urtica*), and the Red Admiral (*V. Atalanta*); the Caterpillars of both feed on the nettle. The Painted-lady Butterfly (*Gynthis Cardus*) is another beautiful species, which is also common everywhere.

The Coppers (*Polyommatus*), and the Blues (*Lycena*), with their brilliant metallic tints, are also very charming, although their size is much smaller than that of the insects above referred to. The species of the genus *Argynnis*, of which one of the commonest is here represented (Fig. 247), are elegantly marked with silvery spots on the lower surface of the wings.



Fig. 247.—*Argynnis Paphia*.

ORDER XI.—HYMENOPTERA.

General Characters.—The order *Hymenoptera*, the first of the mandibulate metabolous insects, includes a vast number of species, amounting, according to the calculations of Kirby and Spence, to about one-fourth of the entire insect world; and some of these certainly exhibit the highest development of instinct, or perhaps the nearest approach to reason, that we meet with amongst invertebrate animals.

These insects are generally distinguishable at the first glance, by the structure of their wings, which are almost always present, and four in number, of a membranous texture, and traversed by a few nervures, which by their union form regular cells. The form and arrangement of these cells in some groups, afford the most important generic characters; and entomologists have distinguished them by particular names. A few species are destitute of wings, and in others the wings present no nervures. The hinder pair is always smaller than the anterior, and the connection between the two wings during flight is usually maintained by means of a series of minute hooks placed on the anterior margin of the hinder wing.

The mouth is always furnished with a pair of strong mandibles, and in most cases with maxillæ and other organs of the usual form; but in many species the maxillæ and labium are converted into a suctorial organ, the construction of which has already been described (p. 383, Figs. 172, 173). The eyes are generally large, and placed on the sides of the head, of which, in the males, they sometimes occupy nearly the whole surface (Fig. 168); the ocelli are usually three in number. The whole body is inclosed in a scaly armour; its three great divisions are usually very distinct, but the thoracic segments are more or less fused into a mass, the prothorax being generally distinct. The legs are generally long, and the tarsi composed of five joints.

The *Hymenoptera* are also distinguished from the other insects with membranous wings, by the presence of an ovipositor of peculiar construction at the extremity of the abdomen in the females, which not only serves for placing the eggs in the required position, but also in many species (Bees, Wasps, &c.) constitutes a most formidable offensive weapon. As the structure of this organ, which is rarely absent, is essentially the same throughout the order, the form of its component parts being merely modified

to suit the exigences of the different insects, a short description of its general construction will not be out of place here. The ovipositor, or sting, generally consists of five pieces; a pair of horny valves (Fig. 248, 1 2), which form a sheath for the true

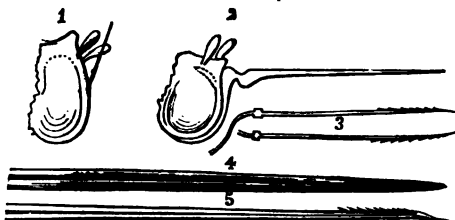


Fig. 248.—Sting of the Bee. 1 2, External valves; 3, bristles; 4, sheath; 5, bristle more magnified.

sting or ovipositor; these are jointed at the point where they issue from the cavity of the last abdominal segment, and the last joint is usually as long as the sting itself. The latter consists of three bristles, of which the superior (Fig. 248, 4) is channelled along its lower surface, for the reception of a pair of finer bristles (Fig. 248, 3 and 5),

which are toothed at the tip. These three pieces, when fitted together, form a narrow tube through which the egg passes to its destination; and through this also the poisonous fluid, which renders the sting of the Bee so painful, is injected into the wound. In the Saw-flies, as we shall see, one of these parts is rudimentary; but in other respects the organ remains the same.

The larvæ of most of the *Hymenoptera* are footless grubs (Fig. 249), usually furnished with a soft head, exhibiting but little, if any, advance upon the maggots of the



Fig. 249.—Larvæ of Bee, nat. size and magnified.

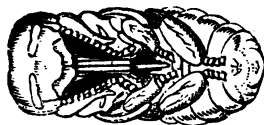


Fig. 250.—Pupa of Bee, magnified.

Diptera. The pupæ are quiescent (Fig. 250), completely enveloped in a delicate skin, each limb being inclosed separately. In the Saw-flies, however, the larva, instead of being, as above described, a mere footless maggot, presents the closest resemblance to the caterpillars of the *Lepidoptera*, being provided with a distinct horny head, and not only with six thoracic legs, but also, in most cases, with from twelve to sixteen pro-legs, situated upon the abdominal segments.

Divisions.—As the differences just referred to in the larvæ of these insects are accompanied by an equal diversity in the structure and mode of life of the perfect insects, we thus obtain an excellent means of dividing the *Hymenoptera* into two sub-orders; those with caterpillar-like larvæ having been regarded by McLeay as diverging so greatly from the rest of the *Hymenoptera*, as to warrant their complete separation. In these, forming the sub-order *Securifera*, the abdomen is attached to the thorax by its whole breadth; whilst in the other sub-order, the *Petiolata*, it is supported on a slender footstalk of greater or less length.*

* The *Hymenoptera* have generally been divided into two great sections, the *Terebrantia* and *Aculeata*, in one of which the ovipositor is employed solely in the operation of egg-laying, whilst in the other it is converted into a sting by its connection with a poison-gland. By this arrangement, however, insects with a very different metamorphosis, and exhibiting a great diversity of general structure, are brought together; and we have preferred adopting the arrangement given above, which appears to be more natural.

SUB-ORDER I.—SECURIFERA.

The *Securiferous Hymenoptera*, of which the perfect insects may always be distinguished by their sessile abdomen, are vegetable feeders in all stages of their existence. They form two tribes, of which one, the *Phyllophaga*, always feed upon the leaves or other soft parts of plants; whilst the *Xylophaga* burrow in the woody portions, and there find their nourishment.

The *Phyllophaga* are distinguished by the peculiar construction of the ovipositor, which has procured them the name of *Saw-flies*, by which they are popularly known.

This organ (Fig. 251), is composed of a pair of broad, serrated plates, the analogues of the inferior bristles of the Bee's sting (see Fig. 248). The superior channelled bristle is considered by Burmeister to be reduced to the form of a tubercle, which keeps the bases of the saws separate, whilst, according to Westwood, this bristle is divided into two parts, represented by the dorsal portion of the serrated plates. This saw-like organ is protected on each side by a jointed horny plate, and the whole is generally received within the lower surface of the last abdominal segment.

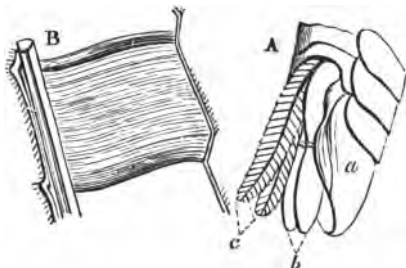


Fig. 251.—A, extremity of the abdomen of the Saw-fly, showing the two saws, *c*, extended; *a*, the terminal joint of the abdomen; and *b*, the two internal horny sheaths. B, a small portion of one of the saws very highly magnified.

By the agency of these curious and elegant organs, the female Saw-fly cuts numerous minute slits in the stems or leaves of plants, in each of which she lays an egg, accompanied by a drop of fluid, which is supposed to have some influence in preventing the closing of the wound, and in some cases the irritation thus set up causes the formation of a gall, within which the larvæ live and feed. As a general rule, however, the larvæ, when hatched, leave their shelter and feed upon the leaves of plants. The species are generally confined to certain kinds of plants, to which, when they are produced in great numbers, they often do immense mischief. Thus the larvæ of the *Athalia centifolia*, known to farmers as the *Nigger* or *Black Caterpillar*, has occasionally done incredible damage to turnips in this country; and that of another species, the *Nematus Grossulariæ*, is not less destructive to gooseberry bushes. The larvæ of other species infest fruits, living and feeding in the interior, and causing them to fall off whilst still immature. They are almost always furnished with pro-legs in addition to the thoracic members.

Before changing to the pupa state, these larvæ usually spin a cocoon, some of them remaining attached to the twigs of the plants infested by them, others burrowing down into the pith, and others again seeking security in the earth. The perfect insects generally make their appearance in the spring or early summer, passing the winter in the pupa state. In the perfect state they frequent flowers; and although generally of small size, and rarely adorned with very brilliant colours, most of them are elegant insects.

In the second tribe, the *Xylophaga*, the ovipositor differs in its structure from that of the Saw-flies, and approaches that of the following sub-order. It projects from the

abdomen, whence the name of Tailed Wasps, popularly applied to the commonest species in this country (Fig. 252), is derived. The second joint of the lateral plates is also prolonged, forming a sheath, within which three bristles are concealed, the upper



Fig. 252.—*Sirex Gigas*.

one being the largest, and channelled beneath for the reception of the two lower bristles. These three bristles, forming the true ovipositor or *borer*, are all serrated at the extremity.

The larvæ, which only possess six small thoracic legs, live in the trunks of trees, especially fir, burrowing through the wood in various directions, and often causing extensive damage. It has been supposed that these insects were parasitic upon the larvæ of other wood-boring insects; but this opinion appears to have arisen entirely from errors of observation. They are rare in this country; but upon the continent of

Europe, where pine forests are more abundant, they often make their appearance in immense numbers, and commit very serious depredations upon the timber. Specimens of *Sirex gigas* (Fig. 252) are occasionally taken in the neighbourhood of London; but these have, in all probability, been imported in the pupa state in timber.

SUB-ORDER II.—PETIOLATA.

The *Petiolata*, distinguished by the maggot-like form of their larvæ, and by the union of the abdomen with the thorax by the intervention of a slender footstalk, form two principal groups, the *Terebrantia* and the *Aculeata*. In the former the ovipositor, although similar in construction to that of the *Aculeata*, appears to be exclusively intended for the business of oviposition. Some species, indeed, will apply this organ to the purpose of self-defence when captured; but even if they puncture the skin, they rarely leave that lasting pain which is so disagreeable an accompaniment of the stings of the true *Aculeata*. By far the greater number of the *Terebrantia* are parasitic upon

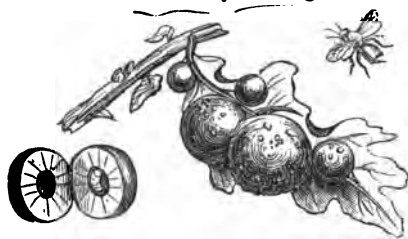


Fig. 253.—Galls of Oak-leaf, and Insect (*Cynips Quercus-folii*).

other insects; but one tribe, that of the *Galliole*, consists almost entirely of vegetable-feeding insects. These are generally of minute size, with straight antennæ, composed of from thirteen to fifteen joints; the wings exhibit only a few nervures, and the palpi are short. Their most striking character consists in the structure of the ovipositor, which is bent into the form of an S within the abdomen, its extremity passing up through a channel

formed by the ventral plate of the last abdominal segment. Its construction otherwise departs in no respects from the general character of the order. By means of

this ovipositor, which can be exerted or retracted at pleasure, the females puncture the leaves, buds, and other parts of plants and trees, depositing an egg in the wound, accompanied probably by some irritating fluid, which causes a diseased growth in the part, and thus produces the excrescences known as *galls*. Within this domicile the larva lives, feeds, and attains its maturity. Here it also undergoes its transformations; and it is not until its arrival at the perfect state that it eats its way out, and becomes a free denizen of the air.

The forms of the galls vary excessively according to the plant on which they are found, and the species of Gall-fly by whose puncture they are caused. The oak is especially subject to the attacks of these insects. The leaves are often covered with small round galls, produced by *Cynips Quercus-folii* (Fig. 253), and several other species attack those organs; whilst the well-known oak-apples are produced by a species (*Cynips terminalis*) which deposits its eggs in the extremities of the shoots. Other species of oaks are equally infested by these creatures, one of which produces the well-known and important galls of commerce (Fig. 254). The Dead Sea apples, which have been the subjects of such frequent controversy, are also galls, produced by the puncture of a small insect described by Mr. Westwood under the name of *Cynips insana*. The spangles of the oak-leaves are also produced in this manner.

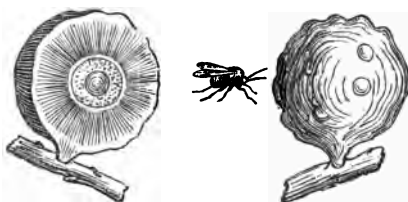


Fig. 254.—The Commercial Gall, and its Insect (*Cynips Gallæ tinctoriæ*).

These excrescences usually contain only a single larva; but in some cases a large family of grubs are concealed in a single gall. A few species are parasitic in their habits.

The second tribe includes an immense assemblage of insects—some of considerable,

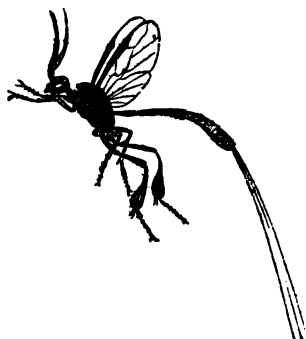


Fig. 255.—Fœnus.

others of minute size—which, from their constant habit of passing their larva state as parasites upon other insects, have received the name of *Entomophaga*. They are distinguished from the *Gallivora* by having the ovipositor of the usual construction, straight, and inserted at the apex of the abdomen. It is sometimes concealed, sometimes more or less exerted, and in the latter case often attains a great length (Fig. 255). When exerted, the ovipositor appears to consist of three bristles; of these the outer pair are the terminations of the sheathes, and the middle one is composed of three bristles, forming a minute tube for the passage of the egg.

Insects of every order, and in every stage of their existence, are subject to the attacks of these parasites, which are well known under the name of Ichneumon and Cuckoo-flies. They introduce their eggs into the bodies of their victims by piercing them with their ovipositor. Minute size is no protection; for many species lay their eggs in

Aphides, *Cocci*, and the larvæ of other small insects. The Ichneumons, with long ovipositors, seek the burrows of wood-boring insects, whose larvæ they are enabled to reach by means of this organ. Each species usually infests a particular species of insect; and, singular as it may appear, many of these parasitic larvæ are again preyed upon by others, whose parents are directed by an unerring instinct to the selection of the proper position for the nourishment of their offspring.

Many of them, and especially the larger species, only lay a single egg in their victim; but the larvæ of many of the smaller species exist in families of a hundred, or even more, in the bodies of caterpillars and other insects. The insect infested often acquires the pupa form before any signs of his internal enemies are perceptible; and many a collector of *Lepidoptera* has been grievously annoyed, when his carefully-preserved chrysalides have produced, as Madame Merian expresses it, nothing but these "little rascally flies." In other cases, generally when a number of these parasitic larvæ have made a common prey of some unfortunate insect, the parasites break out before undergoing their transformation, which then takes place in the interior of a little cocoon, which each of them weaves for itself. This may often be observed in the caterpillars of the common Cabbage-butterflies.

This vast tribe is divided into four great families. In the *Evantiidæ* the abdomen is attached to the upper surface of the metathorax (Fig. 255), and the antennæ are straight; the *Ichneumonidæ* also have straight antennæ; but the abdomen is attached to the extremity of the metathorax. In the *Chalcididæ* and *Proctotrupidæ*, which are generally minute insects, the antennæ are elbowed, and the wings are nearly veinless; but in the former the palpi are short and the pupa is naked, whilst in the latter the palpi are long, and the pupa inclosed in a cocoon.

In the preceding insects the abdomen is composed of six or seven distinct segments; but in the *Tubulifera*, forming the third tribe, it appears to consist only of three or four, or at most five segments; the remainder being converted into a tubular telescopic organ, at the extremity of which a minute sting or ovipositor is situated. The antennæ of these insects, which appear to constitute a transition from the Terebrant to the Aculeate sections, are composed of thirteen joints in both sexes, the basal joint being elongated, and the antennæ bent or elbowed at its extremity.

These insects—of which one species (*Chrysis ignita*) is well known in this country under the name of the *Ruby-tail*—generally exhibit a gem-like brilliancy of colour; the thorax being usually of a fine metallic blue or green, and the abdomen of a most splendid ruby colour. They are generally of small size; and may be seen, in the hottest sunshine of summer, running about upon walls, palings, and sand-banks, in search of the nests of wild bees and other Hymenopterous insects, upon which their larvæ are parasitic. As Mr. Westwood observes, they deserve the name of *Cuckoo-flies* more than any other parasitic insects, as it appears that in most cases their larvæ feed rather upon the store of food laid up for the nourishment of their host than upon the host itself; although they doubtless finish by devouring the rightful inhabitant of their usurped domicile. The lower surface of the abdomen is hollowed out, so that when in danger they can roll themselves up into a ball, and thus, to a certain extent, defy their enemies. This habit is also exhibited by many species of bees. When lying in this condition, in dread of an attack from the bees whose cells they have invaded, the latter have been known to cut off the wings of the marauder, and then throw him from their nest to the ground, trusting that in this maimed condition he could do no further mischief; but so pertinacious is the *Chrysis* in its attacks, that, finding itself incapable

of flight, it has been seen to crawl up again to the bees' nest, and deposit its egg.

We now pass to the Aculeate series of *Hymenoptera*, in which the ovipositor not only serves for the extrusion of the egg, but also conveys a poisonous and apparently acid fluid into the wounds which it inflicts. The antennæ in these insects are almost always composed of twelve joints in the females, and of thirteen in the males; the four wings are veined, and the veins of the anterior pair are always arranged so as to form distinct and regular cells, the number and form of which have been found to furnish valuable characters for the generic groups. The abdomen in the males consists of seven joints, and of six in the females.

We divide the Aculeate *Hymenoptera* into four tribes, of which three are predaceous in their habits, living principally or entirely upon animal matter, whilst the fourth seeks its nourishment entirely in the secretions of flowers.

The first tribe, the *Heterogyna*, including the true Ants, is composed entirely of insects, which live in communities, composed of three distinct kinds of individuals—males, females, and neuters. The males and females are winged, the former during the whole, the latter during a part only of their existence in the perfect state. They make their appearance in great numbers at a particular period of the summer, when they quit the nest in which their preparatory stages have been passed, and copulate in the air. When this has been accomplished, the males speedily die; but the females lose their wings, and crawl about upon the ground, until they fall in with some neuters, which immediately seize upon them, and convey them to their nest. The neuters, as they are called, which form the bulk of the community, are in reality females, in which, probably from difference of food in the larva state, the sexual organs have remained undeveloped. Like the perfect females, they are furnished with a sting. It is upon these that the entire labour of the society devolves; they form the nest, carry off the eggs when laid by the female, and attend to the larvæ, feeding them with the utmost care.

The nests of Ants exhibit a great diversity of structure; but the larvæ are never inclosed (as in the Social Bees and Wasps) in cells. The nest consists of numerous chambers, communicating by winding passages; excavated sometimes in the ground, sometimes in heaps of earth, or other matters raised above the surface, and, in some cases, in the trunks of old trees. Some exotic species build their nests on trees, walls, and the roofs of houses, composing them of earth mixed with other substances, of the excrement of animals, or of vegetable matters. In whatever manner the nest is constructed, however, the chambers in its interior serve for the protection of the larvæ and pupæ, which are carried from chamber to chamber by the workers, so as to ensure their exposure to the temperature best suited for their development. Thus at night the young animals are carefully stowed away in the innermost chambers of the nest; every aperture being kept closed, to prevent the ingress of the cold night-air. But as soon as the rays of the morning sun fall upon the surface of the nest the workers busily commence carrying their infant treasures to the upper chambers, where, close under the roof, they may enjoy the genial warmth. Not unfrequently they even place them for a time on the outside of the nest, exposed to the direct rays of the sun. At the approach of night, or of a shower of rain, the business is reversed; every worker is engaged in carrying the larvæ down into the lower chambers, and in closing up the entrances to the nest against the unwholesome cold or moisture.

Although the Ant has been, from time immemorial, the type of industry and provi-

dence, from a general belief that it laid up a store of grain in the summer season to serve for its support during winter, it is certain that our European Ants are decidedly carnivorous in their habits; although they often evince a great predilection for saccharine juices; and it is not improbable that the idea of their providence may have had its rise from their having been seen, as is often the case, carrying the cocoons in their mouths. These, by a superficial observer, might easily be mistaken for small grains of corn. Colonel Sykes, however, observed an Ant in India, which certainly laid up a large store of grass seeds; and it is possible that other species may have the same habit, one of which may have been in Solomon's eye when he penned his well-known advice to the sluggard. This character for industry will not, moreover, apply to the whole group; for some species have the remarkably lazy habit of making slaves of the workers of other species, whilst they, like feudal barons, devote themselves exclusively to the profession of arms.

The wings of the male and female Ants are carried flat, and usually furnished with but few nervures and cells, and the three segments of the thorax form a roundish or oval mass. In the neuters, the three segments of the thorax are distinctly separated, the middle one being generally smaller than the others, so that the thorax appears constricted at this part;—in all, the first, or first and second, segments of the abdomen, forming the stalk, are furnished with a knob or scale. The males and females possess three ocelli; the workers are destitute of these organs. In some species a second kind of neuters make their appearance, distinguished by the enormous size of their heads and mandibles; these are called *soldiers*, and their office appears to be the protection of the workers whilst engaged in the performance of their various duties. Some species of Ants, inhabiting tropical countries, sometimes come in swarms into houses, from which they quickly expel the inmates, biting and stinging most severely. One of these species, the *Atta cephalotes*, which inhabits the West Indies, is there known as the *Visiting Ant*.

In the second tribe, the *Fossoria*, or *Burrowing Hymenoptera*, we no longer find communities of three kinds of individuals; these insects are solitary in their habits, and both the males and females are usually winged. The wings lie flat upon the back in repose. The tongue is never elongated and thread-like; and the legs are constructed solely for walking and burrowing, and never dilated to form instruments for carrying pollen.

The females of these insects excavate little burrows in wood or in the ground. In the latter case, generally selecting a sandy locality, whence the name of *Sandwasps* is applied to some of them. In these burrows they lay their eggs, accompanied by a



Fig. 256.—*Ammophila sabulosa* making its nest.

supply of food for the use of the larva, consisting of other insects, spiders, &c. These victims are either killed, or reduced to a very passive state, by a sting from the parent insect before being introduced into the burrow. In forming the burrows the jaws and legs are the principal agents, the latter being generally furnished with spines to render them more efficient in throwing out

The insects composing the third tribe, the *Diploptera* (with the exception of a single genus), are distinguished from all other *Hymenoptera*, by having the wings folded longitudinally when at rest, forming a pair of long narrow organs, running down the sides of the body. The tongue is rather long; the maxillæ are long and coriaceous in their texture; and the eyes are notched or kidney-shaped.

The common Wasp (*Vespa vulgaris*) may be taken as the type of this tribe. This insect, as is well known, lives in extensive communities, inhabiting a nest formed in holes of the ground; and here, as in the Ants, we find that the mass of the community is composed of barren females (workers). In the Wasps these are winged, so that the difference between them and the queens, or fertile females, is less striking than amongst the ants. But, in addition to these social Wasps, there is a considerable number which are solitary in their habits, possessing only individuals of the two sexes, perfect males and perfect females, of which the latter form nests or burrows in which they lay their eggs, after stocking them with food, in the same manner as the fossorial *Hymenoptera*.

The nests of the Social Wasps are formed of a paper-like material, prepared by the insects from wood and other vegetable matters, which they masticate until it acquires a pulpy consistence, and then apply it to the building of their nests. The outside usually consists of layers of a rather coarser kind of paper, and the interior of the nest is occupied by a series of transverse combs, composed of hexagonal cells, with the mouths downwards. The combs are united by little pillars formed of the same material. In these cells the eggs are laid, and the larvæ are constantly fed with honey by the workers. A few species even lay up a store of honey like the Bees.

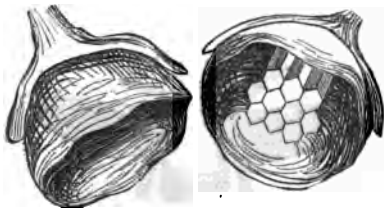


Fig. 257.—Nest of *Vespa Holsatica*, just commenced.

The societies of Wasps are entirely destroyed every year at the approach of cold weather—only the young females survive the winter in a state of torpidity; and when the mild weather of spring again calls them into life, they immediately set about the formation of a nest, in which they lay a few eggs, and attend to the larvæ themselves. The first brood consists entirely of workers, which, on reaching the perfect state, relieve the queen of all labour, and the colony then rapidly increases. It is, however, composed entirely of workers until the end of the summer, when males and females make their appearance.

The Solitary Wasps usually make their nests of clay or agglutinated sand, generally attaching them to walls and palings; a few also burrow in sandy ground. The nest consists of several cells placed close together, and each cell is stored with a supply of insect food for the support of the larvæ.

The last tribe of the *Hymenoptera*, the *Anthophila*, or flower-lovers, is distinguished by having the basal joint of the posterior tarsi dilated and flattened, and often furnished with an apparatus of bristles adapting it for the conveyance of pollen (Fig. 258). The labium and maxillæ are more or less elongated, generally forming a trunk (see Figs. 172 and 173). The perfect insects feed exclusively upon the nectar of flowers, and the larvæ upon this, and upon pollen.

In some Bees, forming the family *Auŕenidae*, the trunk is short and blunt at the

apex. In these it is the basal portion of the lower lip (the *mentum* or *chin*) that is elongated. The posterior legs are not constructed for carrying pollen. These insects are solitary in their habits; the females forming burrows in the ground, in which they deposit their eggs in the midst of masses of pollen and honey. Numerous eggs are laid in the same burrow; each furnished with a separate mass of paste, and divided from its neighbours by a little earthen partition.



Fig. 258.—Hind leg of working Hive Bee.

In the true Bees (*Apidae*) the tongue is elongated, and the mouth exhibits the general construction described at page 333.

In these we meet with a great variety of habits,—some are solitary, and of these some burrow in the ground, like the *Andrenidae*; others form nests in dead wood (*Xylocopa*, Fig. 259); others, termed *Mason Bees* (*Osmia*), construct their cells of grains of sand agglutinated together; and others, again, known as Upholsterer Bees, or Leaf-cutting Bees, line their nests with

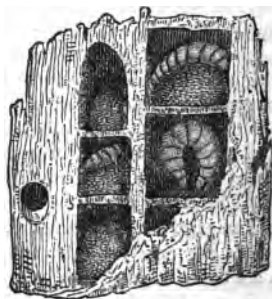


Fig. 259.—*Xylocopa*, or Carpenter Bee, with its nest.

pieces of leaf, which they cut as neatly as if it were done with a pair of scissors. The Cuckoo Bees (*Nomadae*), elegant and gaily-coloured insects, save themselves the trouble of nest-making, by depositing their eggs in the cells of their more industrious brethren.

In the Social Bees, which exhibit the instinctive faculties in their highest develop-

ment, we again meet with three sets of individuals—males, females, and workers. It is upon the latter that the labour of the community, the construction of the nest, and the rearing of the young, generally devolve; although amongst the Humble Bees (*Bombi*) the females also take part in these operations. In these, as in the Wasps, the continuation of the species, from year to year, depends upon the impregnated females,



Fig. 260.—*Bombus lapidarius*, with the jaws of the male and female.

which pass the winter in a state of torpidity, and in the spring construct a small nest,

and bring up their first brood by their own exertions. Besides the neuters we find two kinds of females in the communities of *Bombus*,—the large females, which found the colonies, and smaller ones, which assist in the labour of the nest, and are said to produce only male eggs.

The nests of the Humble Bees are generally constructed of moss. They contain a few waxen cells, in which the young are brought up. Both the females and workers have the basal joint of the posterior tarsi enlarged and excavated, forming what has been termed a basket, for the conveyance of pollen. These are wanting in some species (*Apathus*), which are parasitic in their habits.

In the Hive Bees the society is permanent—that is to say, the workers, as well as the females, survive the winter, during which period their stores of honey are intended for their support. Like those of the Humble Bees, their communities consist of three kinds of individuals, males, females, and neuters (Fig. 261). We never, however, except at the period of swarming, meet with more than one female in the



Fig. 261.—A, Queen; B, Male, or Drone; C, Worker.

hive. The whole duty of the construction of the comb, and the care of the young, devolve upon the workers, whose incessant activity has rendered them the most appropriate types of industry. The comb, as is well known, consists of beautiful hexagonal cells, constructed with mathematical accuracy. It is perpendicular, and composed of a double series of cells, placed end to end in such a manner that the end of each cell is closed by three waxen plates, each of which also assists in completing one of the cells of the other side of the comb. By this arrangement the greatest possible number of cells may be constructed in a given space with the smallest possible amount of material. In these cells the eggs are laid. Here also the larvæ are brought to maturity by the care of the workers; and when no longer required as nurseries for the young, they are employed as a store for honey. The eggs which are to give birth to males are placed in cells a little larger than those of the workers. Those from which females, or

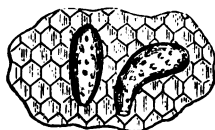


Fig. 262.—Portion of the comb of the Hive Bee, with royal cells attached.

queens, are to be produced, are deposited in cells of peculiar construction (Fig. 262); and the larvæ are fed upon a different food from that of the workers. When the population of the hive has grown too large, a portion of the workers emigrate, accompanied by a young queen; this is termed *swarming*. Many other details relative to these interesting and valuable insects will be found in the works of Entomological writers; and we may refer the reader especially to the Introduction of Messrs. Kirby and Spence, which contains much interesting information on this subject.

ORDER XII.—STREPSIPTERA.

We come now to a small order of minute insects which are parasitic in the interior of numerous species of Bees and Wasps, and the history of which is so singular as to have given rise, for many years, to a great deal of speculation amongst Entomologists. The males (Fig. 263 A B) are rather elegant little creatures, furnished with a single pair (the posterior) of large membranous folding wings, the place of the anterior wings being occupied by a pair of curiously twisted organs. The mouth is provided with slender jaws, and with a pair of palpi; but it appears to be doubtful whether the males take any nourishment after their arrival at the perfect state.

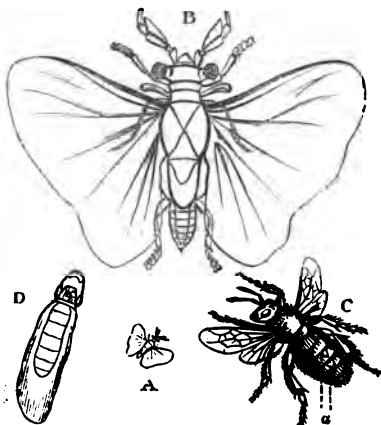


Fig. 263.—*Stylops Dalii*.

A, Male natural size; B, magnified; C, Bee with heads of female; *Stylops a* projecting from between the abdominal rings; D, female magnified.

The females (Fig. 263 D), which were long taken for the larvæ, present the appearance of soft maggots, furnished with a horny head, which they protrude between the segments of the Bee in which they are parasitic (Fig. 263 C), the remainder of the body remaining concealed. On examining this it is found to contain a number of eggs, and to exhibit a broad canal running up to the head, on the under surface of which it opens. Through this opening the male fecundates the eggs, the female never quitting the body of the bee, and the larvæ are hatched within the body of their mother, from which they escape by creeping up the canal above mentioned. In their earliest state they are active, little, six-footed creatures, which were long supposed to be parasites upon the Strepsipterous parasite. They attach themselves to the bodies of Bees and Wasps, by whom they are thus conveyed into their nest. Here they bury themselves in the body of the bee larva, and become converted into soft maggot-like grubs, which continue to feed upon the substance of their victim until the latter arrives at its perfect state.

The only further change which the female undergoes consists in the hardening of the head and the development of the generative organs. The male, however, becomes converted into a pupa within the skin of the larva, the head of which also becomes horny, and protrudes like that of the female from between the rings of the Bee. When the male is ready to emerge, this horny piece is thrown off like a lid, and the perfect insect quits his former residence.

During their existence in this state, which is probably very short, the males are very active, flying about in the sunshine with a buzzing noise. The antennæ often exhibit very singular forms, being sometimes forked, or branched, and sometimes pectinated. The eyes are generally very prominent; they consist of but few facets; and these are separated from each other by raised partitions, which give a curious cellular appearance to their surface.

The position of these insects in the system has always been a puzzle to Entomologists, and can scarcely yet be considered settled. By some authors they have been placed amongst the *Hymenoptera*; by others amongst the *Diptera*; by others as intermediate between these two orders, or between the second order and the *Lepidoptera*. In their general structure, however, they appear to approach the *Coleoptera*, amongst which they are arranged by some recent Entomologists; and their proper position is probably between the *Coleoptera* and the *Hymenoptera*.

ORDER XIII.—COLEOPTERA.

General Characters.—The leading characteristic of the vast order of *Coleoptera*, or Beetles, consists in the leathery or horny texture of the anterior wings (*elytra*), which serve as sheaths for the posterior wings in repose, and generally meet in a straight line down the back. The posterior wings are membranous and much larger than the anterior pair (see Fig. 180); they are the sole organs of flight, and are folded both longitudinally and transversely when not in use. They never exhibit the radiating folds and nervures which we have seen to be universal in the hind wings of the *Orthoptera*.

The mouth in the *Coleoptera* is always formed for biting, and perhaps exhibits the mandibulate type of structure in its highest perfection (see Fig. 178, p. 332). The labrum is generally distinct, although sometimes concealed beneath the front of the head. The mandibles are almost always strong, somewhat triangular, horny organs, which, in the predaceous Beetles, are hooked and sharp at the points, and often armed with acute teeth on the inner margin; whilst in many herbivorous species the inside of the basal portion is transversely ridged to fit the jaws for the comminution of vegetable substances. In some Beetles, which feed upon fluid matters, the mandibles are dilated into membranous hairy plates. In some cases, as in the common Stag-beetle (Fig. 91), the mandibles are of great size, and some allied species have them still larger.

The maxillæ exhibit differences in form corresponding with those of the mandibles. In the carnivorous beetles they are usually acute and somewhat hooked at the tip; whilst in the vegetable feeders they are generally blunt at the extremity, and frequently fringed with hairs. They are always furnished with one pair of palpi, consisting of three or four joints; and in many carnivorous Beetles the outer lobe, which was described as forming a hood-like covering in the *Orthoptera*, acquires the form of a second palpus. The labium is also furnished with a pair of palpi, composed of from two to four joints.

The other organs attached to the head are the antennæ and the eyes. The antennæ exhibit a great diversity of form, numerous examples of which will be referred to in the sequel. They are generally composed of from nine to eleven joints, and are inserted upon the forehead between the eyes, sometimes close to those organs, sometimes more in the middle of the head. Compound eyes exist in nearly all Beetles; they are placed on the sides of the head, and are generally of a more or less spherical form, sometimes oval or kidney-shaped, and in a few cases divided into two parts by an elevated ridge; so that the insect appears to have four eyes; whilst in a few Beetles, inhabiting caves or other subterranean situations, the eyes are entirely wanting.

The thoracic segments are always distinctly separated. The prothorax is usually of considerable size, and bears the first pair of legs. The meso- and metathorax bear

the other two pairs of legs, and the elytra and wings, beneath which their upper surface is entirely concealed, with the exception of a small triangular piece of the mesothorax (the *scutellum*), which is usually visible at the base of the suture. The elytra generally cover the entire dorsal surface of the body, to the apex of the abdomen, and the upper portion of these segments is then of a soft and somewhat membranous texture; but in some cases the elytra are short, leaving a greater or less portion of the abdomen uncovered; this is then equally horny on both surfaces. In some cases the wings are wanting, when the elytra are not unfrequently completely soldered together.

The legs are usually constructed exclusively for walking; but in some cases the fore legs are converted into fossorial organs, and in others the hind legs are flattened for swimming, or furnished with thickened thighs for saltatorial purposes. The tarsi are generally composed of five joints; and this appears to be the normal number. The number varies, however, in different groups, from two to five.

The metamorphosis of the *Coleoptera* is as complete as in the *Lepidoptera* and *Hymenoptera*. The larva is usually a soft fleshy grub; although the texture of its integuments is often leathery, or even somewhat horny, especially in the rapacious species. The soft larvæ are almost always furnished with a horny head, armed with distinct jaws, and usually furnished with simple eyes. They are generally furnished with six thoracic legs (although these are sometimes wanting), and frequently also with anal pro-legs. The pupæ are free and quiescent.

This order includes an immense number of species. It is supposed that between thirty and forty thousand are already known; and it cannot be doubted that many more still remain to be discovered.

This multiplicity of species has necessitated the formation of a great number of groups; and so complicated is the classification of the *Coleoptera*, that (although, with the exception of the *Lepidoptera*, no other order of insects has so much engrossed the attention of Entomologists,) it is still in rather an unsatisfactory state. Latreille divided these insects into four principal sections, characterized by the number of joints in the tarsi; and although this character is liable to many exceptions, and can only be regarded as applying to the majority of the insects in each group, yet, as it furnishes us with the best means of effecting the general division of the order, we shall follow it here to a certain extent. In the largest of these sections, the greater number of the insects have five joints in the tarsi; these form the section *Pentamera*. In a second group, the *Heteromera*, most of the insects have five joints in the tarsi of the two anterior pairs of legs, whilst the posterior tarsi are composed of only four joints. In the *Tetramera* all the tarsi are usually four-jointed, and in the *Trimera* three-jointed.

SECTION I.—TRIMERA.

In this section, which only includes a single tribe, the tarsi apparently consist of three joints; although a fourth minute joint really exists at the base of the last joint, concealed within the bilobed apex of the second. From this circumstance Mr. Westwood has proposed the substitution of the name *Pseudotrimera*, for that of *Trimera*. The antennæ are short and usually clavate; the maxillæ bilobed, with shortish palpi, usually terminated by a hatchet-shaped joint; and the body is either oval or hemispherical, and very flat beneath.

An excellent example of this tribe of Beetles is afforded by an insect that must have been familiar to most of us from our earliest years,—the Common Lady-bird (*Coccinella*

7-punctata). The numerous species of *Coccinella* feed principally upon *Aphides*, both in the larva and perfect states. The larvæ of our common species are constantly to be met with on plants infested by *Aphides*; they are of a slate colour, with yellow tubercles and spots, and furnished with six well-developed legs. They attach themselves by the tail before changing to the pupa state. The colours of the perfect insects run from red or yellow, with or without black spots, to black, with or without red or yellow spots; and as all this variety of colour may occur in individuals of the same species, the determination of the species in this group is excessively difficult. When touched or disturbed, the Lady-birds draw their legs close up to the body, emitting at the same time a yellow and somewhat acrid fluid, which, according to some writers, is a specific for the tooth-ache.

SECTION II.—TETRAMERA.

The majority of the insects, composing the three tribes included in this section, have only four apparent joints in all the tarsi, the true fourth joint being reduced to a very small size, and concealed within the one preceding it. As this joint exists, however, Mr. Westwood has proposed the addition to the name of this group of the same prefix as to the *Trimeræ*; he accordingly calls these insects *Pseudotetramera*.

In the first tribe, the *Phytophaga*, the body is usually of a more or less ovate form, generally very convex, rarely elongated; the head is short, not produced into a snout, immersed in the thorax up to the eyes; the antennæ are shortish, usually thread-shaped, or slightly clavate; the mandibles are small, the maxillæ bilobed at the apex, with the outer lobe often jointed and palpiform; the palpi are short.

These insects rarely attain any great size, and many of them are very minute; their colors, however, especially in the larger exotic species, are often very splendid; in some cases, perhaps, exceeding in brilliancy those of any other Beetles. They feed upon plants, both in the larva and the perfect state; and many of them do great damage



Fig. 264.—*Chrysomela populi*. a, Larva; b, Pupa; c, Imago.

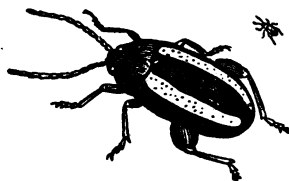


Fig. 265.—Turnip-fly; natural size and magnified.

to crops. The Turnip-fly (*Halicta nemorum*, Fig. 265), one of the most destructive species, belongs to a group in which the posterior thighs are much thickened for jumping.

The most singular insects belonging to this tribe are the *Cassididae*, or Helmet Beetles (Fig. 267), in which the body is rather flat, margined all round with dilatations of the thorax and elytra. The dilated portion of the former completely conceals even the head. They are slow-moving animals, which always draw up their limbs and mimic death when disturbed. Their larvæ are furnished with a caudal fork, projecting forwards over the back. Upon this they collect their excrement, which thus forms a portable shelter.

The insects of the tribe *Longicornia* are generally distinguishable from all other



Fig. 266.

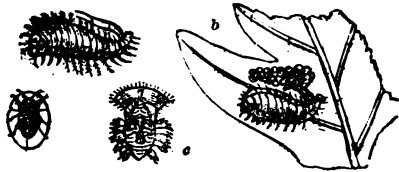


Fig. 267.

Fig. 266.—*Acanthocinus speculifer*.

Fig. 267.—*Cassida viridis*, in its different states. a, larva; b, the same on a leaf, with its covering of excrement; c, pupa; d, perfect insect.

Beetles by the great length of their antennæ (Fig. 266), which are usually considerably longer than the body. The body is usually elongated in its form; the head is never produced into a rostrum; the mandibles are large and prominent, and the labrum is usually distinct.

Most of these are large and elegant insects, often adorned with splendid colours, or armed with spines upon the thorax and other parts of the body, which render their appearance curious and even grotesque.

Their antennæ are usually filiform, or tapering towards the extremity; but in some cases they are toothed or pectinated, and, in a few, adorned with singular tufts of hair. The legs are long and formed for walking, but often exhibit curious modifications; the elytra and wings are well developed.

One of the handsomest British Beetles is the *Callichroma moschata* (Fig. 180), belonging to this tribe. It is also distinguished by its peculiar musky odour. It is of a fine metallic green colour; but many exotic insects nearly allied to this, are far more splendid in appearance.

The larvæ of these insects live in timber, often doing enormous injury to trees by eating large passages through the solid wood. They are soft, fleshy grubs, generally widened in front, almost destitute of feet. They appear to live in this condition for several years, and afterwards probably pass a considerable time in the pupa state, as the perfect insects have been known to eat their way out of timber which had been for some time worked up into furniture. These Beetles generally produce a sharp grating sound, by the friction of the back of the prothorax upon the base of the scutellum.

The *Rhynchophora*, forming the third tribe of Tetramerous Beetles, are distinguished by having the front of the head produced into a snout or rostrum, at the extremity of which the mouth is situated. The antennæ are placed on the sides of this rostrum, sometimes at the base, sometimes at the apex, and in all intermediate positions. They are generally geniculated; that is, furnished with a long basal joint, at the extremity of which the remainder of the antennæ, which consists of shorter joints, is bent. The extremity of the antennæ is more or less clavate. The tarsi are four-jointed.

The larvæ are soft, footless grubs, which usually live in the interior of the stems, fruits, and seeds of plants, to which their ravages are often very injurious. Amongst these the Corn-weevil (*Calandra granaria*) holds the first place, as its larva frequently causes great damage in granaries. One of the commonest species is the *Balaninus*

nucum (Fig. 268), or Nut-weevil, the parent of the little white grubs so frequently met with in filberts and other nuts. This insect has the longest rostrum of any British Rhynchophoreus Beetle, and by means of this the female is said to eat a small hole in the young nut whilst its integuments are still soft. Here she deposits an egg, and the larva when hatched eats its way into the interior of the kernel, where it continues to reside until it has arrived at maturity. It then eats its way out of the nut, and falls to the ground, into which it burrows, and there undergoes its transformation to the pupa state, which, however, does not take place until the commencement of the second summer. The history of the other species of the tribe appears to be very similar, although many pass to the pupa state attached to, or inclosed within the substances upon which they have been feeding in the larva state.

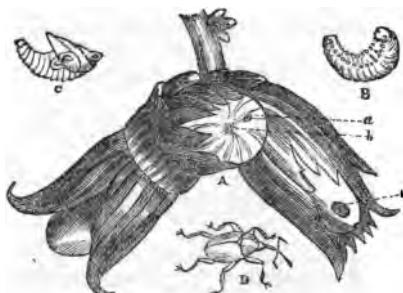


Fig. 268.—A, a branch of the filbert tree; a, a healed wound caused by the introduction of the egg of the Nut-weevil; b, extremity of the nut; c, exit hole of the grub; B, the grub of the nut-weevil; C, the pupa of the same; D, the perfect insect (*Balaninus nucum*).

Most of the *Rhynchophora* are more or less covered with minute scales, somewhat resembling those with which the wings of the *Lepidoptera* are clothed; and these, in many cases, exhibit a splendour of colour scarcely, if at all, inferior to that of the most gorgeous of Butterflies. Even amongst our small British species, several of great beauty are to be met with on every bank of nettles; and few insects can boast of greater magnificence than the well-known Diamond Beetle of Brazil (*Curculio imperialis*).

The insects just referred to, all possess geniculated antennæ; but the habits of those with straight antennæ differ but little from those of their allies. One of the best known is the *Bruchus pisi*, the larva of which is very common in the seeds of the pea; and to such an extent does this insect abound in some localities, that it has sometimes occasioned the entire destruction of the pea crops. Another species, *Rhynchite Bacchus*, attacks the buds and leaves of the vine, to which it often does immense injury in the wine countries of Europe.

A considerable number of the true *Rhynchophora* burrow in their larva state into the stems of trees, often forming holes of considerable diameter in the solid wood. They are, however, completely outdone in this respect by the insects of the following sub-tribe, which have received the name of *Xylophaga*, from their constant habit, both in the larva and perfect states, of boring into the solid wood of trees. In their general structure they resemble the *Rhynchophora*; but their heads are broad and flat, not distinctly rostrated, and the antennæ are inserted beneath the lateral margins of the head.

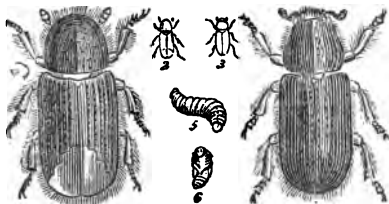


Fig. 269.—1, 2, *Tomiscus typographus*. 3, 4, *Hy-lurgus piniperda* (natural size and magnified). 5, 6, Larva and pupa of *Hy-lurgus*.

Although these insects are of small size,

the damage which they occasion in forests is often enormous. The *Scolytus destructor*,

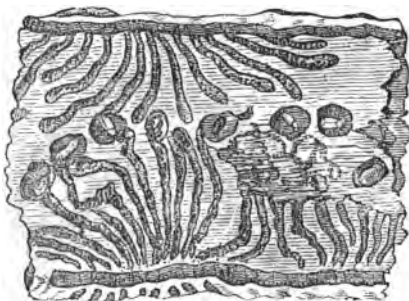


Fig. 270.—Track of *Tomicus typographus*.

a common British species, destroys great numbers of elm-trees; but the ravages of some other species, in the pine-forests of Germany, are almost incredible. Of these the commonest are the *Tomicus typographus* and the *Hylurgus piniperda* (Fig. 269). The former receives its name of the Typographic Beetle from the circumstance that the burrows formed by it in feeding upon the soft wood, immediately within the bark, often present a rude resemblance to printed characters (Fig. 270). The devastations

of these apparently contemptible foes are sometimes so formidable, in the pine-forests of Germany, that prayers for their restriction are offered up in the churches; and we are told that, in the year 1783, at least a million and a half of trees were destroyed by these insects in the Hartz forest alone.

SECTION III.—HETEROMERA.

Nearly all the insects of this section of the *Coleoptera* have four joints in the posterior tarsi; whilst the other four feet are composed of five joints. They are divided by Mr. Westwood into two tribes—the *Trachelia*, in which the head forms a distinct neck behind the eyes, and the *Atrachelia*, which possess no distinct neck, the head being immersed up to the eyes in the thorax.

The *Trachelia* are generally active diurnal insects, frequently adorned with gay colours. Their bodies are often soft, the elytra flexible, and sometimes much shorter than the abdomen. To this tribe belongs the Blister-fly (*Lytta vesicatoria*, Fig. 271), the important medicinal uses of which are so well known. These insects are common in the south of Europe, and specimens have occasionally been met with in England;

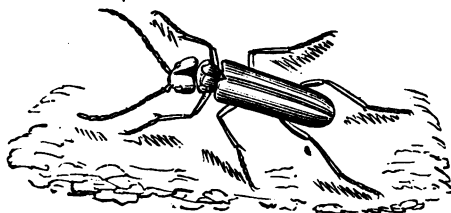


Fig. 271.—*Lytta vesicatoria*.

they feed principally upon the ash. Many other insects belonging to this tribe also contain a substance which has the effect of raising blisters when applied to the skin; and these are employed in their native countries in place of the *Lytta vesicatoria*. The species of *Meloe*, several of which are found in Britain, possess this property; which, however, seems in all cases to increase in intensity in proportion to the heat of the country in which the insects live. The species of *Meloe* are soft, sluggish Beetles, with short elytra and no wings, which may be found crawling about amongst the grass, in warm sandy places, in the early summer. The young larvæ, on first leaving the egg, closely

resemble those of the *Strepsiptera* already described (see p. 398); and as they attach themselves in the same way to wild bees, it is supposed that they are afterwards parasitic upon the bee larvæ. Hence some entomologists regard the *Strepsiptera* as a group of *Coleoptera* nearly allied to these. The curious *Rhiphorus paradoxus*—a small Beetle also belonging to this group—is parasitic in the nests of the common Wasp; and many other species appear to be parasitic in their larva state. One of the most beautiful of the British species is the scarlet *Pyrochroa rubens*, which is found about hedge-banks in the neighbourhood of London. In the *Salpingide*, which appear to connect this group with the preceding, the front of the head is produced into a short snout.

The *Atrachelia* are generally black, or of dull colours, nocturnal in their habits, and slow in their motions, usually crawling upon the ground in obscure situations. A few are found upon trees and plants; and these, in their structure, evidently approach the preceding tribe.

A very good example of this group is furnished by the common *Blaps mortisaga* (Fig. 272), which bears the not particularly inviting English name of the Churchyard Beetle. These insects are generally found in dark and dirty places about houses, in cellars and similar situations. Another species is the *Tenebrio molitor*, of which the larva, found in flower, meal, &c., is well known as the Meal-worm. Other species live under the bark of trees, and in decaying vegetable matter; but comparatively few are found in this country.



Fig. 272.—Churchyard Beetle (*Blaps mortisaga*).

SECTION IV.—PENTAMERA.

It is in this section that we find the greatest variation in the number of joints in the tarsi. A great number of the insects of which it is composed would require to be distributed amongst the preceding sections, if we allowed none but truly Pentamerous beetles to be arranged here; these, however, are exceptions to the general rule, and the majority of the insects placed in this section have tarsi composed of five distinct joints.

As the number of Pentamerous Beetles is very great, and they exhibit a corresponding diversity of structure and habit, their subordinate divisions are, of course, very numerous. They may, however, be divided into eight principal tribes, of which six have the outer lobe of the maxillæ of the usual form, whilst in the other two it is jointed and palpiform (see Fig. 171, c). Of the former, the *Serricornia* are principally distinguished by the structure of their antennæ, which are usually rather elongated, filiform, or tapering towards the extremity, and serrated or pectinated. The penultimate joint of the tarsi is often bilobed.

In some of these insects, forming the sub-tribe *Malacodermata*, the body is usually soft, and the insects, in their general form, present a considerable resemblance to many of the first group of *Heteromera*. They are further distinguished from the *Sternozia*, forming the second sub-tribe, by having the prosternum of the ordinary form, and not produced into a spine posteriorly. Many of these, such as the insects well known to children as *Soldiers* and *Sailors* (*Telephori*), are predaceous in their habits, whilst others are wood-borers, and some feed on dry animal substances. Of the wood-boring species, one, the *Lynezyon navale*, infests oak timber, to which it frequently does incredible mischief in dockyards. It is common in the north of Europe, but appears to be rare

in England. Other species, which also bore into timber in their larva state, are well known by the name of the "Death Watch" (*Anobium*, Fig. 273), from their habit of making a ticking noise by knocking with their jaws against the woodwork upon which they are standing. They are little creatures, which often do great damage to furniture in houses. When touched, they contract their legs and counterfeit death,—a piece of mimicry which they are said to keep up even when exposed to a heat sufficient to



Fig. 273.—*Anobium striatum*, natural size and magnified.



Fig. 274.—Glow-worm (*Lampyris noctiluca*), male and female.

roast them. To this group also belongs the Glow-worm (*Lampyris*, Fig. 274), whose lamp has so often been the theme of the poet's song. The female alone is luminous. It is a flat, grayish-brown creature, quite destitute of wings. The male, on the contrary, is active, and flies well; and the luminosity of the female appears to be intended to attract her volatile companion. The larvæ of some species of the genus *Clerus* live parasitically in the nests of Bees and Wasps, feeding upon their larvæ.

In the *Sternozia* the prosternum is produced in front into a lobe, and behind into a spine, which is received in a small cavity of the mesosternum. By the assistance of this apparatus (the spine being drawn out of its groove and then suddenly brought into it again) many of these insects (the *Elateridae*) are enabled to execute considerable springs, when laid upon their backs. The larvæ of some species are wood-borers; those of others live in rotten wood; and some inhabit the ground, feeding upon the roots of plants. One of the latter is well known to agriculturists as the Wire-worm.

Some of these insects are luminous in the dark. They are the Fire-flies of tropical countries. The light is emitted from two large oval spots on the thorax. Others are remarkable for the metallic splendour of their colours; of these (*Buprestidae*) very few are found in Europe; but the exotic species are numerous, and often attain a large size.

The vast tribe of the Lamellicorn Beetles (*Lamellicornia*) is characterized by having the antennæ terminated by a club, composed of several leaf-like joints, laid together like the leaves of a book. This tribe includes an immense number of species, some of which are amongst the largest and most splendid of insects. In the Stag Beetle (*Lucanus cervus*, Fig. 91), the leaves are short and distinct, rendering the club pectinated; whilst in the common Cockchafer (*Melolontha vulgaris*) they are of considerable length, especially in the male, and fold up like the leaves of a fan. These insects fly well, but heavily, with a loud whirring noise; but they generally crawl slowly. The larvæ are thick fleshy grubs (Fig. 275), furnished with a distinct head, and with six jointed feet, and have the hinder part bent down. They live in very various situations, in dung, in decaying vegetable matter, and in the earth, feeding upon roots. They usually pass several years in the larva state, and change to the pupa in the interior of

a sort of cocoon, formed of particles of the surrounding materials, agglutinated together by a sticky secretion (Fig. 275).

Many of the perfect insects are found in the same situations as their larvæ, especially in the case of the Dung-feeding species. Of those which live in rotten wood, many, like the beautiful Rose-chaffer of our own country (Fig. 275), and its still more splendid foreign allies, frequent flowers in their perfect state; and the common Cockchafer, the larvæ of which feeds upon, and often does great mischief to, the roots of plants, lives entirely upon leaves, after it has undergone its last change.

Many of the Dung-beetles, amongst which the Sacred Beetle of the Egyptians (Fig. 276), holds a prominent place, are remarkable for inclosing their eggs in a small pellet of dung, which they then roll along with their hind legs, until they drop it into a hole which they have dug for its reception. Others, like the common *Geotrupide* and *Aphodiide* of our own country, are contented with depositing their eggs in the midst of a plentiful supply of food. The forms of some of these insects are extremely curious;

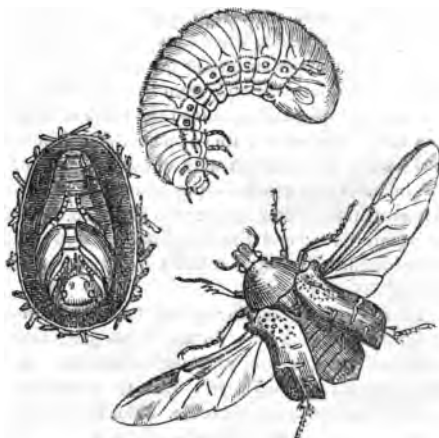


Fig. 275.—Larva, Pupa, and Imago of the Rose-beetle (*Cetonia aurata*).



Fig. 276.—*Scarabæus Egyptiorum*.

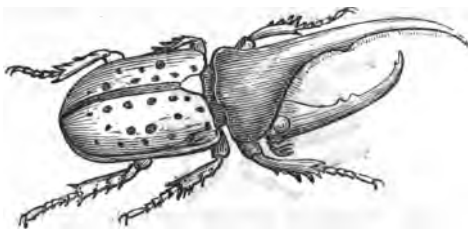


Fig. 277.—*Dynastes Hercules* (reduced).

and many of the larger tropical species are furnished with enormous horns on the head and thorax, which give them a singular appearance. The *Dynastes Hercules* (Fig. 277) is one of the most remarkable of these. It is a native of Brazil, and is one of the largest Beetles; sometimes attaining a length of five inches.

The classification of the insects which we refer to the four following tribes, and the arrangement of the latter, are still in a most unsatisfactory state; and almost every writer upon this branch of Entomology puts forth views different from those of his predecessors.

In the *Helocera*, which appear to make the nearest approach, both in structure and habits, to the Lamellicorn Beetles, the antennæ are terminated by a knob, composed of several joints, which are sometimes pressed closely together, and sometimes loosely connected, so as to give the club a serrated appearance. They are further distinguished by their flattened contractile limbs, each portion of which folds closely upon its neighbour; the whole, when thus reduced to the smallest compass, being received in cavities of the lower surface of the body. This position is always assumed by these Beetles when alarmed; and, from this assumption of a death-like attitude, some of the commonest species have received the name of *Mimic Beetles*. These insects, both in the larva and perfect states, are commonly found in cow-dung; a few also inhabit rotten wood; some are to be met with under the bark of trees, and a few in carrion. This tribe includes two groups:—the *Histerida*, smallish insects, generally of a black colour, with geniculated antennæ, and the elytra rather shorter than the body, which is usually of a square form; and the *Byrrhida*, with straight antennæ, and the elytra as long as the abdomen. The latter are of a round or oval form, whence they have received the name of *Roll-beetles*.

The next tribe, the *Necrophaga*, includes an immense number of small and moderate sized insects, which live for the most part, both in the larva and perfect states, in decomposing animal and vegetable substances. A good many are also found under the bark of trees, and in *Fungi*. Like the preceding insects, these have clavate antennæ, but their legs are not contractile. The nearest approach to the preceding tribe is made by the *Dermestida*, small Beetles, clothed, like the *Byrrhida*, with minute hairs, which often do great damage to skins and furs, and other dry animal matter. The commonest species, *Dermestes lardarius*, has received its specific name on account of the fondness exhibited by its curious larva for bacon.

The largest and most interesting insects belonging to this tribe, are those of the family *Silphida*, which includes the Burying Beetles (*Necrophori*, Fig. 278) and their allies. The Burying Beetles are prompted by their instinct to bury any small animals, or pieces of carrion, as a provision for their young. In many cases several of them set to work together, getting under the animal to be buried, and digging the earth out with



Fig. 278.—Burying Beetle (*Necrophorus*).

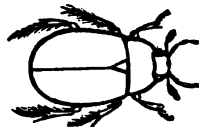


Fig. 279.—*Hydrophilus Caraboides*.

their feet. In this way they will quickly bury animals many times their size, such as mice and small birds. These insects are not uncommon. They run and fly well; and some of them are adorned with bright orange-coloured bands; but they diffuse a most abominable odour, arising probably from the nature of their food.

The insects of another small tribe, called *Philhydrida*, from their generally aquatic habits, also have clavate antennæ, but these are usually very short, whilst the maxillary palpi are of great length, and often longer than the antennæ. Most of these insects live constantly in the water; and their legs are generally more or less flattened, to render them efficient as natatory organs (Fig. 279). One of the largest British Beetles,

the *Hydrous piceus*, which is not uncommon in ponds in some localities, belongs to this tribe. It also includes a group of small hemispherical Beetles (the *Sphaeridiidæ*), which constantly inhabit dung. The aquatic species are carnivorous in their habits, and the larger ones will often attack young frogs and fishes.

We now come to a group, the location of which has given much trouble to entomologists, as, although it is undoubtedly nearly allied to the *Necrophaga*, its introduction in the neighbourhood of that tribe always appears to interrupt some natural affinities. The active predaceous habits of some of the larger species, of which the *Goërius olens* (Fig. 280) is a very common example, seem also to point to an alliance with the true

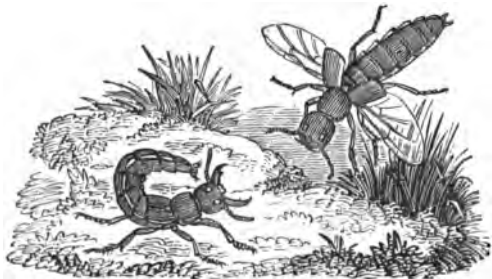


Fig. 280.—*Goërius olens*.

carnivorous Beetles; and, on the whole, this is perhaps the most natural position for these insects. They are characterized by their generally filiform antennæ, and by the shortness of their elytra, which always leave a considerable portion of the abdomen uncovered. The name *Brachelytra*, given to the tribe, refers to this character. The wings, however, are usually ample, and the insects fly well. They are generally of an elongated form; and the abdomen, which is horny on both surfaces, possesses great mobility. It assists in tucking the wings under the elytra after flight; and the insects generally raise it when alarmed or angry. This attitude has been obtained, for the insects figured above, the appropriate name of *Cocktails*. The derivation of their other vulgar denomination, *Devil's Coach-horses*, is not so clear. The larvæ are very similar to the perfect insects, both in appearance and habits. Many of them feed in carrion; others in rotten wood, and other decaying vegetable matters. The number of joints in the tarsi varies greatly, but five is the prevalent number.

In the two following tribes, which close the series of Coleopterous insects, the outer lobe of the maxillæ is jointed and palpiform, so that these insects appear to have six palpi. They are pre-eminently carnivorous and rapacious in their habits.

The former, constituting the tribe *Hydradephaga*, are characterized by their somewhat flattened oval body, and by having the legs, especially the hinder pair, compressed and fringed with bristles, so as to become powerful paddles. Many of these insects are of considerable size, the *Dytiscus marginalis* (Fig. 281), a species very common in ponds, attaining a length of more than an inch; whilst many foreign species are much larger. The larva is of an elongated form, tapering towards the tail, which bears a pair of tubular ciliated appendages, which the creature applies to the surface of the water to obtain a supply of air for its respiration. It is as predaceous as its parent, seizing upon other aquatic larvæ with its long curved mandibles, and quickly sucking the juices out of the body of its victim. These mandibles are perforated throughout, and it is through these tubes that the larva sucks its nourishment. When about to change to the pupa state, the larva burrows into the bank of its native pond, and there undergoes its transformations. The well-known *Gyrini*, or *Whirligigs*—little black Beetles, which may be seen describing circles upon the surface of any piece of water—

are also placed in this tribe, although their claim to such a position is rather doubtful.

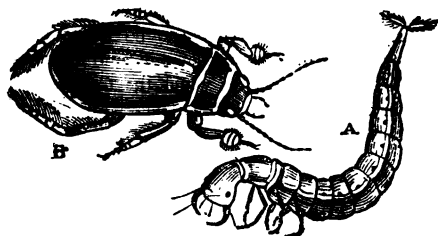


Fig. 281.—*Dytiscus marginalis*.
A, larva; B, perfect insect.

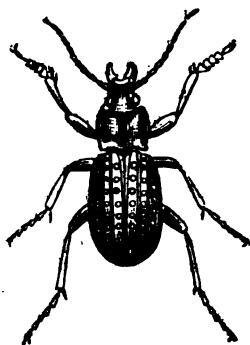


Fig. 282.—*Carabus*.

The insects of the last tribe, the *Geodephaga*, resemble those of the preceding group in their carnivorous propensities, and in the structure of their mouths; but their legs are always constructed for terrestrial progression. They are exceedingly active, and often beautiful insects; generally nocturnal in their habits, concealing themselves during the day under stones and in holes in the ground. The larvae are elongated, flattened, and usually covered with a horny integument. In their predaceous habits they resemble the perfect insects.

The insects of one family, the *Cicindelidae*, which have received the name of Tiger-beetles, from their eminently predaceous propensities, are more diurnal in their habits than the rest of the tribe; the common English species, *Cicindela campestris* (Fig. 283), may be found flying and running about with great agility in the hottest sunshine. This insect is of a beautiful green colour, with whitish spots; and its mouth is armed with a most formidable pair of sharp, toothed jaws. The larvae are of a singular form; they live in holes in the ground, maintaining themselves by means of a pair of hooks placed on the enlarged eighth segment of their body, at such a height that their heads exactly occupy the mouth of the hole. Here they lie in wait for their prey, which consists of other larvae; and the moment one of these approaches their den, they rush upon it with the greatest ferocity, and bear it off in their jaws.

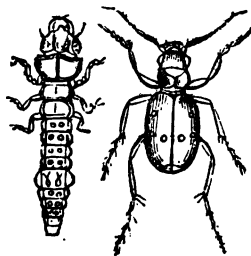


Fig. 283.—*Cicindela campestris*.

DIVISION IV.—MOLLUSCA.

General Characters.—The MOLLUSCOUS division of animals consists of creatures whose bodies are universally of a soft consistence. They are inclosed within a soft, flexible skin, called the *manile*, which possesses great contractile power; and their

motions are principally performed by the extension and contraction of part of their substance. The symmetrical arrangement of all the organs on each side of a central line, so remarkable in the preceding division, here almost disappears, or is only recognizable in the position of the organs of sense attached to the head. The nervous system consists either of a single ganglion, giving off filaments to the various organs of the body, or of several ganglia, placed somewhat irregularly in different parts of the body, communicating by nervous threads with a larger mass placed in the head, or in the neighbourhood of the œsophagus. This mass consists of several ganglia, of which the more important, constituting the brain, are placed above the œsophagus. These are generally accompanied by other ganglia placed below that organ, which are united by filaments with the supracœsophageal ganglia, or brain; thus forming a ring surrounding the œsophagus. The supracœsophageal ganglia furnish the nerves to the special organs of sense placed upon the head. The ganglia belonging to the different organs of the body communicate with the ring surrounding the œsophagus.

Most of the *Mollusca* possess special organs of touch, in the shape of tentacles, arms, or lobes, situated on the head or in the neighbourhood of the mouth, or of cirri upon other parts of the body. In addition to these organs, the skin, which is always soft, appears to possess great sensibility. The tentacles of the *Mollusca* are either two or four in number; they are capable of being completely retracted into the head by a process very similar to the turning in of the finger of a glove, and are again exerted by reversing the process. The eyes, when present, are two in number, sometimes placed immediately on the head, sometimes supported at the extremity, or on the sides, of the tentacles. In the highest class the visual organs attain a perfection equal to that exhibited by the fishes,—the lowest class of vertebrated animals.

In some of the lower *Mollusca* small coloured points are met with, sometimes singly in the neighbourhood of the brain, sometimes in considerable numbers on the edges of the mantle. These, from their structure and appearance, have received the denomination of *ocelli*, and have been regarded as rudimentary eyes,—a determination which, although it may be correct in some instances, is very doubtful in others. It is remarkable, also, that many species, which are quite destitute of eyes when arrived at their mature form, are furnished with those organs at their first issuing from the egg.

Auditory organs appear to be possessed by nearly all the *Mollusca*. They usually consist of small vesicles placed close to the cephalic ganglia, containing a clear fluid and a small calcareous concretion (*otolithe*), which is sometimes of a roundish, sometimes of a crystalline figure, and is in a perpetual state of vibration. The senses of smell and taste also appear to be exercised, to a certain extent, by most of these animals; but whether any organs specially devoted to these functions really exist, must still be considered doubtful.

The movements of the *Mollusca* are generally executed by means of a muscular organ, called the *foot*, which varies greatly in its form, in accordance with the habits of the creature. The foot consists of a mass of muscular fibres, running in various directions, by the contraction of which its movements are effected. In a great number of *Mollusca* the foot forms a flat disc (Fig. 284), which adheres to any substance to which it may be applied, and thus, by the alternate contraction and dilation of its different parts, enables its possessor to crawl



Fig. 284.—*Conus hebraicus*.

slowly along. In others, the foot is bent upon itself, so that its sudden extension causes the animal to perform a considerable leap. The foot is also the agent by means

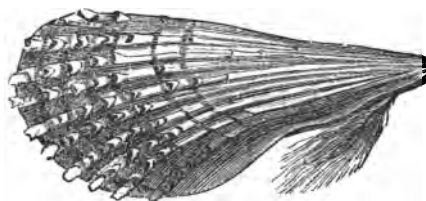


Fig. 285.—Pinna, with its byssus.

of which the burrowing species bury themselves in the sand or mud; and in the species whose instincts lead them to bore into the solid rock, it is also called into requisition: its surface in these cases being covered with minute silicious particles, which assist greatly in the enlargement of its owner's stony dwelling. But

although most *Mollusca* possess a greater or less power of motion, others are confined to a single spot, during all but the earliest period of their existence. These have no occasion for a foot, and in them this



Fig. 286.—Octopus Hawaiensis.

organ is either wholly undeveloped (as in the oyster), or serves merely to support a glandular organ, from which a silky matter (called the *byssus*) is secreted, which serves

to attach the animal to submarine objects. This modification occurs in the common Mussel (*Mytilus edulis*); but it is still more remarkable in the *Pinnæ* (Fig. 285), in which the silky matter is of a very fine texture, and so abundant that it is woven into small articles of wearing apparel, such as gloves and stockings.

In the highest class of *Mollusca*, the *Cephalopoda*, the mouth is surrounded by a variable number of arms (Fig. 286), which not only serve as organs of motion, but for the capture of prey. To render these efficient prehensile organs, they are covered on the inner surface with numerous cup-like sucking organs.

The intestinal canal in the *Mollusca* presents almost every variety of form, from a simple cavity to a complicated intestine. It is, however, always furnished with two openings, a mouth and an anus, the latter being frequently situated on the side of the body, not far from the anterior extremity. The liver is always of great size, generally enveloping all the other intestines.

The circulation of the blood is effected by means of a distinct heart, which usually communicates with a regular vascular system; but, in some instances, the circulation takes place in a system of sinuses or cavities amongst the organs of the body. In the former case the heart is often composed of two or more chambers, from which large arteries arise to convey the blood to the various organs. It is again collected in the veins, through which it passes to the neighbourhood of the respiratory organs, where it is aerated by contact with the surrounding medium, and then passes to the heart. As most *Mollusca* are aquatic in their habits, their respiration is almost always effected

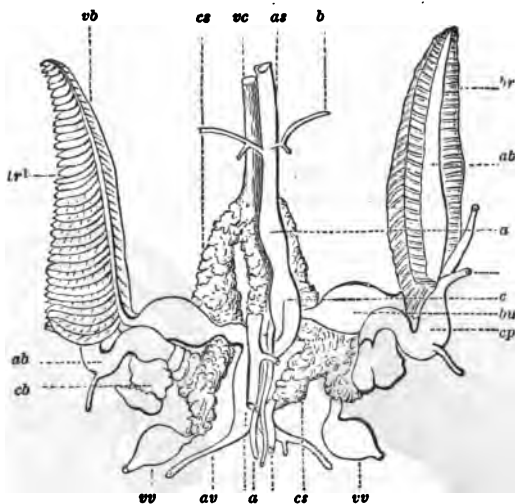


Fig. 287.—Organs of circulation and respiration in the Cuttle Fish (*Sepia*).

c, heart; as, superior artery; a, ventral artery, with its branches av; cc, principal vein, or vena cava; cb, branchial hearts; br, branchiæ; vb, branchial vein; bu, bulb of branchial vein; ab, branchial arteries; vv, ventral veins.

by means of branchiæ (Fig. 287). These are usually composed of a series of minute laminae, or of broad plates, over which the water flows. They are sometimes attached to the surface of the body, but generally inclosed within the mantle, or placed in a

cavity in its interior, called the *branchial* or *respiratory chamber*. The water necessary for respiration is sometimes drawn into this cavity, and again expelled by muscular contraction. In this case its recoil frequently serves to drive the animal slowly through the water, and some species swim with great rapidity in this manner. In other cases, the inner walls of the canals, through which the water passes, are lined with cilia, by the action of which a constant current is kept up. Not unfrequently these

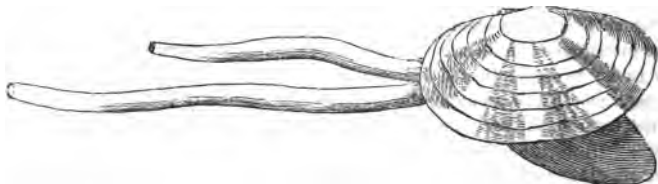


Fig. 288.—*Psammobis*, with long siphons.

canals are drawn out into tubes (Fig. 288), called *siphons*, which are often of great length in the burrowing species.

The air-breathing species, of which the common Snails and Slugs are well-known examples, are furnished with a pulmonary sac or lung, into which the air penetrates; and where it comes in contact with the blood contained in the numerous vessels with which the walls of the sac are supplied. Many of these animals live in water; but they are compelled to come to the surface to breathe; and all of them appear to require a moist atmosphere.

Most of the *Mollusca* are protected by a hard calcareous covering or shell, which is secreted by the mantle, and is gradually increased in size, in proportion to the growth of the animal. In many this is composed of a single piece (Fig. 289), which is usually a spiral tube, gradually increasing in size towards the open extremity, from which the animal protrudes itself when in action. Shells of this description are called *univalves*. In others the shell is composed of two pieces or *valves* (Fig. 290), attached to each other

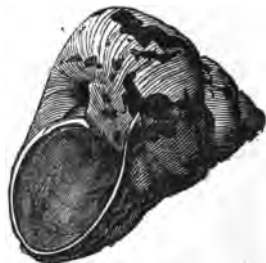


Fig. 289.—Univalve Shell (*Trochus*).



Fig. 290.—Bivalve Shell (*Pectanculus*).

at one point by a hinge, which is usually furnished with an elastic ligament, serving to open the valves, when the tension of peculiar muscles, whose office it is to keep the shell closed, is removed. This is denominated a *bivalve* shell. These differences in the

structure of the shell correspond with differences in the conformation of the animals. The bivalve *Mollusca* exhibit no traces of any distinct head; whilst, in the univalves, this part of the body is well-marked, and usually furnished with special organs of sense (tentacula, eyes, &c.)

The older naturalists also recognised a group of multivalve shells, or shells composed of several valves. The majority of these belonged to the Cirrhopod order of *Crustacea* (page 296), which were regarded as *Mollusca* by the earlier observers. The *Pholades*, however, which in other respects are true bivalve *Mollusca*, are furnished with a pair of accessory plates in the neighbourhood of the hinge; whilst the Chitons (Fig. 291), a small but singular group of *Mollusca*, nearly allied to the univalve Limpets, have an oval shell composed of eight moveable plates, which give them a great resemblance to enormous Woodlice; and they have been regarded as forming a sort of transition towards the Articulated Division.



Fig. 291.—Chiton (side view).

Many *Mollusca* are not furnished with a shell, or have only a small calcareous plate inclosed within the mantle. These are called naked *Mollusca*; but it is remarkable that most of them are provided with a small shell at their first quitting the egg. In the shell-bearing or testaceous *Mollusca*, this embryonic shell, which often differs greatly in shape and texture from the shell of the mature animal, forms the commencement of the latter, additions being constantly made to its free edge by the secretion of calcareous matter at the edge of the mantle.

Shell consists principally of carbonate of lime, with a small quantity of animal matter. The calcareous matter is deposited in the cells of the edge of the mantle, which are in contact with the free margin of the shell. In these it gradually increases in quantity, until they harden, and become attached to the previous shell formation. In this manner, as the animal continues growing, these attached portions of the mantle are thrown off, and left behind; and it is usually only at the margin of the shell that the deposition of new shelly matter is effected. The delicate membranous part of the mantle, which lines the interior of that part of the shell inhabited by the animal, has, however, the power of secreting a thin layer of shelly matter upon the inner surface. This is frequently of a pearly lustre; and in many bivalves a new layer of this substance is deposited at the same time that the size of the shell is increased by additions to its margins,—for, it must be observed, that the formation of new shell is not constantly going on, but appears to be subject to periodical interruptions, indicated by lines on the surface of the shell; these are called lines of growth. In many cases the margin of the mantle, instead of being even, presents lobes or tubercles, which produce corresponding irregularities, ribs, tubercles, or spines, on the surface of the shell (Fig. 292). In this manner, as the spines and other projections are usually formed at the mouth of the shell, at the close of each period of growth, the surface of the shell becomes more or less covered with a series of these prominences, each of which indicates the conclusion of a period of increase. When these spines stand in the way of the further growth of the shell the creature is able to remove them, probably by the action of some solvent fluid.

The shell is almost always coated with a layer of animal matter (the *epidermis*), of greater or less thickness. It is of a horny consistence, and serves to protect the shell from the action of the carbonic acid, which is often dissolved in great quantity, espe-

cially in fresh water. It is in fresh-water shells that this layer of epidermis attains its greatest development, and the colours of these are generally due to it. In many places, however, the epidermis is an insufficient protection against the corroding action of the water, which often eats deeply into the substance of the shells of the *Mollusca* which make it their habitation.



Fig. 292.—*Murex*.

Sexual reproduction prevails amongst the *Mollusca*; and it is only in the lowest forms that we meet with gemmiparous propagation. The sexes are generally on separate individuals; but hermaphroditism is not uncommon. Nearly all these animals are also truly oviparous, although a few produce living offspring; the ova being retained in the oviduct until the exclusion of the young animals. The eggs vary greatly in form. They are sometimes, as in the Land-snails, laid separately, each inclosed in a shell of variable consistence; but in most cases they are agglutinated together into a mass, which sometimes takes the form of a ribbon, attached by one of its edges to some submarine body. In some marine species the eggs are inclosed in

leathery capsules, which are often united to form a large mass. Each capsule contains numerous eggs.

The young Mollusk, whilst still in the egg, is almost always furnished with a delicate, pellucid shell, even when it is ultimately to be naked. In this case the embryonic shell is cast soon after the young animal makes its escape from the egg. The young of the sedentary species, also, are active at this stage of their existence, swimming freely about in the water, until they select some spot in which to take up their permanent abode.



Fig. 293.—Egg of *Lynceus*, with the embryo.

Divisions.—Although these are the general characteristics of the animals belonging to the Molluscan division, those forming the two first classes, the *Bryozoa* and the *Tunicata*, and especially the former, differ from the other *Mollusca* in so many respects, that they have been formed into a separate subdivision, the *Molluscoids*. They are distinguished from the true *Mollusca*, by the very low development of the nervous system, which is composed only of a single ganglion, placed in the neighbourhood of the œsophagus, and giving off nerves in various directions. Of these two classes, the *Bryozoa* are characterized by the presence of tentacular organs in the neighbourhood of the mouth, whilst the *Tunicata* are destitute of such organs.

SUB-DIVISION I.—MOLLUSCOIDA.

CLASS I.—BRYOZOA.

General Characters.—The class of *Bryozoa* is composed of small animals, which always grow together upon a common stock, in the same manner as the compound Polypes, with which they were formerly arranged. Each animal resides in a separate cell, within which it can usually retract itself entirely; the cells are sometimes soft and flexible, sometimes horny, and sometimes calcareous. They frequently stand upon short footstalks, rising from a tubular stock, which creeps over the surface of stones and aquatic plants, in the same way as the horny stems of many of the hydroid polypes. In other cases the cells are sessile, forming a crust upon submarine objects, whilst in others the colony is attached only by its base, with the opposite extremity floating freely in the water. In these the stock is more or less branched, and often leaf-like.

The cells are in general partially free; but in some of the stony species they form a calcareous mass, presenting some resemblance to the true Corals, from which, however, they may always be distinguished by the absence of the calcareous partitions which the latter invariably exhibit. In some species the cells are closed by a cover when the animal is withdrawn; but this protection is generally wanting; and in the species with flexible cells, the complete retraction of the animal draws in the edges of the cell, which then close the aperture entirely. The interior of the cell is lined by the skin of the animal, and the cavity of the body is filled with fluid, in which the intestinal canal floats freely. It also contains the muscles by which the animal protrudes and retracts itself.

The fluid, which is perfectly clear and transparent, is kept in constant motion by the action of cilia, with which the inner surface of the cavity, and the outer surface of the intestine, are covered; and this movement, which extends into the tube of the common stock, is interesting to the naturalist, as it is apparently equivalent to a true circulation of the blood.

The most characteristic peculiarity of the *Bryozoa* is their possession of ciliated tentacula placed at the anterior extremity of the body. By the action of the cilia a sort of vortex is produced in the water, by which the minute animals that constitute the food of the creature are carried down into the mouth, which is placed between them.

These tentacles probably serve also as respiratory organs, as they communicate at their bases with the general cavity; and the fluid with which this is filled appears to circulate in the tentacles by ciliary action. The mouth leads into a muscular oesophagus, below which, nearly at the bottom of the cavity of the body, the stomach is situated. The intestine springs from the upper part of the stomach, near the point where the oesophagus enters, and leads to an anal opening, situated just below the tentacula. These parts are well shown in the engraving (Fig. 294), which affords a good illustration of the subject.

The colonies of the *Bryozoa* are, of course, increased by gemmiparous reproduction; but the establishment of new colonies takes place by the ordinary mode of propagation by ova; and it is somewhat singular that in these sedentary animals the sexes are frequently, if not always, on separate individuals. The sexual organs are attached

either to the surface of the intestine or to the inner wall of the cavity of the body. They

are seen at the bottom of the stomach in the central individual of the group figured (Fig. 294).

The contents of these organs (ova and spermatozoa) appear to be set free in the cavity of the body, where they are carried from place to place by the currents of the nutritive fluid, and in this manner come in contact. The impregnated eggs escape into the water through a minute aperture placed close to the anus. The embryo breaks out of the egg in the form of a ciliated animalcule, which swims about for some time without change. It then becomes cup-shaped, and by degrees

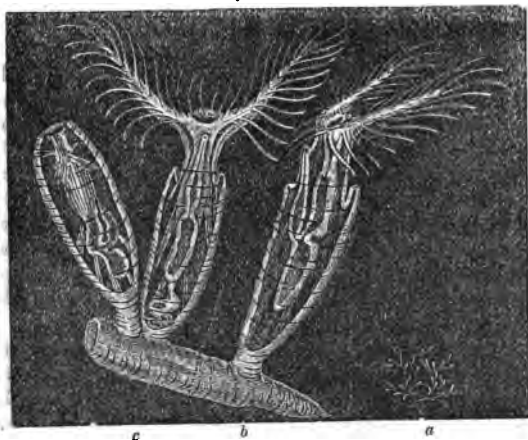


Fig. 294.—*Plumatella*.

a, a group of the natural size; *b*, three individuals magnified; *c*, anus.

The individual on the left is completely retracted within its cell; that in the middle is seen from behind, and that on the right from the side.

tentacles make their appearance at its upper margin, when the little creature fixes itself by its lower extremity, and becomes a simple *Bryozoon*. The changes which the *Bryozoon* undergoes, are curious. It soon begins to form buds at its base, or gives off a creeping stem from which these arise at intervals; and in this manner a new colony is formed. In some cases the development of the embryo presents very remarkable phenomena. A ciliated embryo is produced in each egg; and in the interior of this, whilst still inclosed in the egg, two little *Bryozoa*, furnished with tentacula, make their appearance. The embryo then makes its escape, swims about for a time, and then attaches itself, when the little creatures inclosed in it break out, and lay the foundation of a new colony.

Divisions.—The *Bryozoa* form two very distinct orders. In the *Infundibulata*, the animals, which are all marine, are characterized by having the tentacles placed in a circle round the mouth (Fig. 295); whilst in the *Lophopoda*, which inhabit fresh water, these organs are situated upon two arms given off from the sides of the body (Fig. 294).

ORDER I.—INFUNDIBULATA.

The common *Flustra*, or *Sea-mats*, so abundant on our shores, are well known examples of this order. They are flat and foliaceous in their form, presenting a considerable resemblance in appearance to pale brown sea-weeds, with which they are in fact generally confounded by sea-side visitors. But when carefully examined, these leaf-like bodies will be found to consist of a multitude of small horny cells, opening at

the surface; and from each of these, when the polypidom is placed alive in a vessel of sea-water, the little creatures may be seen protruding their tentacles. Many nearly allied species grow upon the fronds of sea-weeds, over which they spread like a thin coating of gauze, composed of similar cells, opening of course only on one side. Others are found incrusting stones and other submarine bodies with a cellular calcareous mass. In many species the cells are arranged so as to form a more or less thread-like, branching polypidom; whilst others are furnished with a creeping root, from which the cells rise by stems of greater or less length.

Some of the marine *Bryozoa* possess singular organs, the use of which has not yet been satisfactorily made out. These are attached to the polypidom, and from their close resemblance in form to the head of a bird, have received the name of *Avicularia*. They consist of a larger upper and a smaller lower piece; the latter being moveably articulated to its fellow; and the whole is frequently attached to the polypidom by a short footstalk. These organs are constantly in motion, and at the same time the two pieces frequently separate and close again, with a snapping movement, exactly like that of a bird's bill.



ORDER II.—LOPHOPODA.

In this order, composed of inhabitants of fresh water, the tentacles, which are more numerous than in the preceding, are placed upon a pair of long arms, which spring from the sides of the upper extremity of the animal, and usually describe somewhat the form of a horse-shoe (Fig. 294). Their cells are usually of a leathery texture, nearly transparent, and usually spring from a rootstock of similar consistence, which creeps along upon the surface of stones or aquatic plants, in which situations these animals are not uncommon. In some species, however, the polypidom floats freely in the water (*Cristatella*), and is of a gelatinous consistency; in these the animals composing each colony are usually three or four in number.

CLASS II.—TUNICATA.

General Characters.—The animals forming the class *Tunicata*, generally present the appearance of shapeless gelatinous masses. They are composed of two tunics; an outer, the *mantle*, and an inner tunic, which lines a large respiratory cavity. These tunics are continuous at the extremities of the body, where there are large openings; and the animal thus constitutes a tube, furnished with double walls, which are usually separated by a considerable space (Fig. 296). In the numerous compound *Tunicata* we find a modification of this structure. The animals forming one of these colonies are usually united by their mantles, which form a more or less gelatinous mass, in which the individual animals appear to be imbedded. In many of these the body, or at all events the respiratory chamber, is bent round; so that the incurrent and excurrent orifices are brought to the same extremity of the body. In others the posterior apertures of several animals lead into a common canal.

The outer tunic, which is composed wholly or in great part of a substance apparently identical with the woody fibre of plants, is usually of a tough or somewhat cartilaginous texture. The inner tunic is frequently furnished with a variable number of muscular bands, by means of which the internal cavity is contracted so as to expel the water which has entered for the purpose of respiration. The space between these tunics is occupied by a system of sinuses, through which the blood circulates.

The water usually enters the respiratory chamber by the anterior orifice, and is then expelled by the posterior. In the free-swimming species this expulsion of the water constitutes the only means of locomotion possessed by the animal, which progresses slowly in the direction opposed to the stream of water. The respiratory function appears to be performed to a great extent by the lining membrane of the respiratory chamber; but the animals are also furnished with true branchiæ, which present two

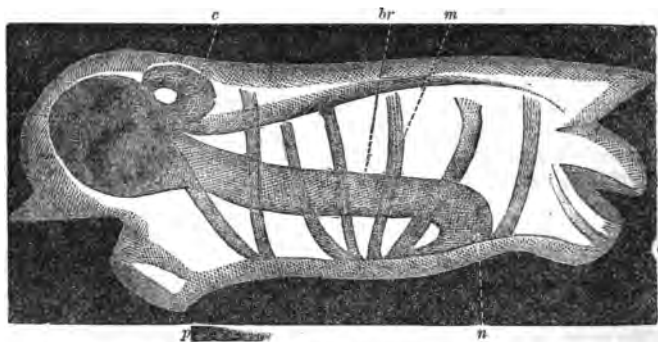


Fig. 296.—*Salpa*.

a, anterior orifice; *p*, posterior orifice; *f*, intestinal sac; *c*, heart; *br*, branchial chamber; *m*, muscular bands; *n*, ganglion.

different forms. In the *Salpa* (Fig. 296), the branchia constitutes a flat or roundish band running through the respiratory chamber, furnished with cilia on its sides; in the other *Tunicata*, the branchial cavity contains a loose network formed of ciliated filaments, crossing each other at right angles.

The intestinal canal is situated near the posterior part of the cavity of the body, opening by a simple mouth from the upper part of that cavity. The mouth leads into a winding intestine, which again opens by another aperture into the respiratory chamber.

The heart is usually placed in the neighbourhood of the digestive organs; it is of a somewhat tubular form, and the blood is set in motion by a gradual contraction of its walls from one end to the other. In their circulation, if circulation it may be called, the *Tunicata* exhibit a remarkable difference from all other animals. The blood does not circulate always in the same direction; but after a certain number of pulsations in one direction the heart rests for a time, when its contractions commence anew in the opposite direction, so that the blood really ebbs and flows.

The nervous system consists of a single large ganglion, placed towards the anterior part of the animal, at its lower surface. Close to this is placed a vesicle containing otoliths, and therefore probably an auditory organ; although, from the presence

of pigment spots upon the otoliths, it has been regarded as an eye by many observers.

The *Tunicata* are all hermaphrodites; and it appears probable that some of them, at any rate, are self-impregnating. The male and female organs have been detected in many species at the posterior extremity of the body, near the digestive system; but the former have been described as a liver. Besides sexual reproduction, however, many of these animals propagate by gemmation, some forming compound colonies, whilst others exhibit a regular "alternation of generations."

Divisions.—The *Tunicata* have been divided into two orders, characterised by differences in the form of their respiratory apparatus. The *Ascidia* have the branchial organ composed of a network of square meshes; whilst in the *Biphora* it consists of a band running through the branchial chamber.

ORDER I.—ASCIDLE.

General Characters.—This order consists entirely of animals which are either attached by the base to submarine objects, or united together in various ways; sometimes by the coalescence of their mantles, so as to form a gelatinous mass, and sometimes by means of a sort of common stalk, very similar to the polypidom of the *Bryozoa*. The efferent orifice of the branchial chamber accordingly, in almost every case, opens in the same direction as the inhalent orifice, either by the canal being bent round within the body of each animal, or by its communicating internally with a common canal of larger size, serving for several individuals. The young of the fixed Ascidians, when first produced from the egg, are furnished with a long tail, which gives them very much the appearance of minute Tadpoles. By means of this they swim about freely in the water, until the time arrives for them to attach themselves. The tail then gradually disappears; the internal organs make their appearance, and the animal soon acquires the form of its parent. In some of the compound Ascidians, however, a somewhat different process has been observed. The tailed embryo is formed in the egg, but this loses the tail whilst still inclosed. Several embryos surrounding a common canal are then formed in the substance of the original embryo, which thus constitutes the nucleus from which a new colony is produced by gemmation.

Divisions.—The Ascidians form four great groups, or large families. In the com-



Fig. 297.—*Botryllus*.

compound Ascidians, or *Botryllidae* (Fig. 297), the animals are united together by the coalescence of their mantles, so as to form a leathery or gelatinous mass, usually attached to stones or sea-weeds; in this the separate animals are imbedded, generally arranged in a more or less distinctly stellate form, round a common efferent canal. Many of them are adorned with beautiful colours.

The second family, the *Clavellinidae*, contains the social Ascidians, or those in which the bodies of the animals are united, not by the mutual adherence of their outer

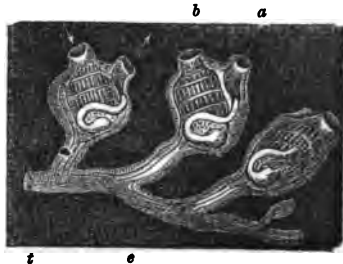


Fig. 298.—*Perophora*.

t, common stem; e, stomach; i, intestine;
b, inhalent orifice; a, efferent orifice.

tunica, but by means of a sort of creeping stem which runs along the surface of submarine objects, and gives rise at intervals to short footstalks, at the extremity of which the animals are supported (Fig. 298). The separate animals are produced by gemmation from the creeping stems, which run in various directions from the base of the original founder of the colony.

The family of simple Ascidiæ, *Asciidæ*, is composed of animals which live separately, attached by the base to submarine bodies. They usually form shapeless masses of a cartilaginous texture, often of considerable size, which occur in great abundance in shallow water. A few species are caten in some countries. The incurrent and excurrent apertures are both situated on the upper surface of the animal, and the former is fringed with tentacles, which appear to prevent the ingress of injurious matters into the respiratory cavity.

The fourth family, the *Pyrosomatidæ*, appears to form a distinct transition from the *Asciidæ* to the following order. In the structure of the respiratory organs they agree with the former; and like the majority of these they are compound animals; but the branchial chamber runs straight through the body, with the openings at opposite extremities; as in the *Salpæ*, with which they also agree closely, in the general arrangement of their organs.



Fig. 299.—Pyrosoma (reduced).

The colonies of these singular creatures are in the form of a cartilaginous tube, open at one end. In the walls of this tube, formed by the coalescence of the mantles of the animals composing it, the bodies of the Ascidiæ are separately imbedded; the branchial chamber of each passing completely through the wall from its outer to its inner surface. These animals are found in the seas of warm climates, where they float along in an upright position, but apparently possess no actual locomotive power. Like all the *Tunicata* they are luminous in the dark, and, in fact, appear to possess this faculty in a greater degree than any other members of the class. Their cylindrical form, upright position, and considerable size (they often attain more than a foot in length), render them exceedingly beautiful objects at night; and they have been described as resembling little columns of fire.

ORDER II.—BIPHORA.

This order includes a group of free-swimming animals, usually of a glassy transparency, the bodies of which may be compared to a tube, furnished with two openings, one for the entrance and the other for the exit of water. The walls of this tube are composed of a distinct outer and inner tunic, the latter furnished with bands of muscles, by the contraction of which the water is forced out of the cavity of the body, producing a recoil, which drives the creature in the opposite direction. The internal structure of these animals has already been described. They are distinguished from those of the other order by the bandlike form of the branchia. The intestines form a small mass above the posterior portion of the branchial cavity (Fig. 296); this is usually of a reddish or yellowish colour, and emits a phosphorescent light in the dark; it is called the *nucleus*.

The reproduction of these animals is attended with some very remarkable circumstances, which were, indeed, the first facts accurately observed in favour of what, for want of a better term, we must still denominate "the alternation of generations." Two forms of *Salpæ* have long been known and regarded as, at all events, specifically

distinct from each other. In one of these the individual animals are united together by their sides into a sort of chain, the movement of which through the water is effected by the simultaneous expulsion of water from the respiratory chambers of all the animals of which it is composed. In the other form the animals are always solitary; and these differ so much in their external appearance, and even in some points of internal anatomy,—such as the number of muscular bands in the inner tunic,—from isolated individuals of the social forms, that it is not at all surprising that they were long considered as distinct species. Accurate observations, however, commencing with those of Chamisso, published in 1819, have shown that each species of *Salpa* possesses individuals of these two forms. The associated forms are furnished with genuine reproductive organs, and produce a single young *Salpa* of the solitary form; and this again produces, by internal gemmation, a chain or series of young animals of the form of its parent. The processes by which these different results are produced are exceedingly curious and interesting. The solitary *Salpæ* exhibit at the hinder extremity, close to the heart, and connected with that organ, a single vessel, divided down the middle by a longitudinal partition. Through this the blood circulates, passing up on one side of the partition and down on the other. Upon the outer surface of this, which is called the *gemmiferous tube* by Mr. Huxley, the associated *Salpæ* are produced, making their appearance at first as mere buds, but gradually increasing in development with age; and those at the hinder extremity of the tube being much further advanced than those nearer the heart. When mature, these young animals quit the body of the parent by an aperture in the posterior extremity of the outer tunic, sometimes singly, at others in a united chain, in which the animals adhere to each other with a very variable degree of force. Each of these animals possesses both male and female organs, the latter furnishing, apparently, but a single ovum. It seems very doubtful, however, whether the animals are self-impregnating, as Mr. Huxley remarks, that in the species examined by him the male organs did not appear to have arrived at their full development when the formation of the embryo had commenced, which, indeed, takes place before the associated *Salpa* leaves the body of its parent. It is singular that these animals are not oviparous, but truly viviparous; the embryo being suspended within the branchial cavity of its parent, and connected with the circulatory system of the latter by a distinct vessel, through which the blood may be seen to pass, the embryo also exhibiting a distinct circulation of its own; phenomena so closely in accordance with those presented by the *Mammalia*, or truly viviparous *Vertebrata*, that naturalists have applied the name of *placenta* to the vascular connexion between the parent *Salpa* and its young. As the young *Salpa* increases in size and perfection, its connexion with its parent is gradually narrowed, until at last it breaks away altogether, and swims off as a free and perfect being.

The *Salpæ* are found in all seas, but most plentifully in those of tropical climates, which are often filled with them in such numbers that the voyager sails for days through masses of these little gelatinous creatures. At night they are exceedingly luminous; and the chains of the associated forms especially are said to present a beautiful appearance.

SUB-DIVISION II.—MOLLUSCA PROPER.

Divisions.—In the great sub-division of the true *Mollusca*, of which the general structure has already been sufficiently explained, we may distinguish five great classes, of which two are unprovided with any distinct head (*Acephala*), whilst the remainder present a head furnished with organs of sense (eyes, tentacles, &c.) Of the former, which are

always furnished with a bi-valve shell, the *Palliobranchiata* are distinguished by having no special breathing apparatus or gill, and by the presence of a pair of ciliated and usually spiral arms attached to the sides of the mouth (Fig. 301), the action of which carries the particles of food towards that aperture; whilst in the *Lamellibranchiata*, or ordinary bi-valve Mollusca, these arms are wanting, and the respiratory function is performed by laminae gills.

The Cephaloporous *Mollusca* are divided into classes by characters derived in a great measure from the form and position of the organs of motion. Thus the *Pteropoda* are small Mollusks, which swim freely on the high sea by means of a pair of fin-like



Fig. 300.—*Creseis subulata*.



Fig. 301.—*Lingula anatina*, showing the ciliated arms.

expansions attached to the sides of the body, at or near the head (Fig. 300). The *Gastropoda* are furnished with a fleshy foot, by the agency of which they creep slowly along (Fig. 284); whilst the *Cephalopoda* (Fig. 286) have a circle of arms surrounding the head, with which they not only crawl upon submarine objects, but also seize their prey.

CLASS III.—LAMELLIBRANCHIATA.

General Characters.—The Lamellibranchiate, or ordinary Bivalve *Mollusca*, are usually inclosed within a bilobed mantle, which, however, in some instances, is entirely closed, with the exception of apertures left for the admission of the water required for the respiratory process, and for the protrusion of the foot (Fig. 302). In all cases, however, the two sides of the mantle produce a calcareous shell, which is always composed essentially of two valves; although, in some instances, they undergo such modifications as to render the recognition of their original structure almost unrecognizable. The two lobes of the mantle are always united at the upper part, where they are also attached to the sac inclosing the body of the Mollusk. At this part, also, the two valves of the shell are attached to each other by a sort of hinge, almost always furnished with teeth, which fit into corresponding cavities in the opposite valve, and are usually provided with an elastic ligament, which unites the two valves along the

hinge-margin, and with an internal cartilage. The office of these elastic bodies is to

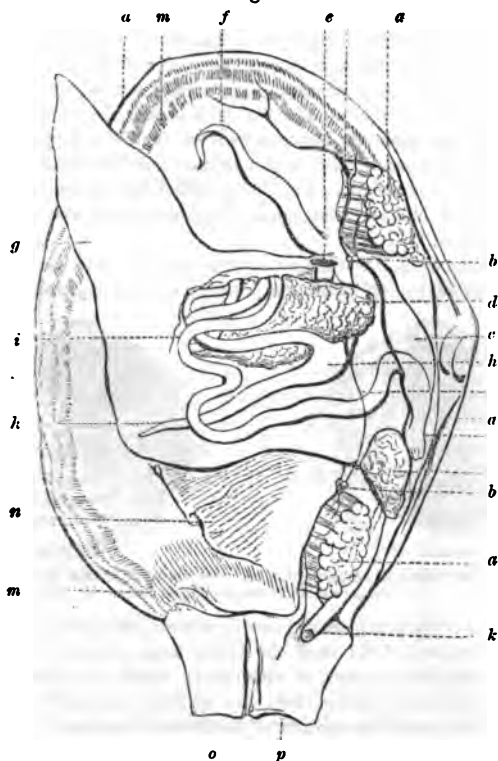


Fig. 302.—Anatomy of a bivalve Mollusk (*Mactra*).

a, shell-muscles; b, ganglia; c, heart; d, liver; e, mouth; f, labial tentacles; g, foot; h, stomach; i, intestine; k, anus; m, mantle; n, branchiae; o, base of inhalant siphon; p, base of exhalant siphon.

open the shell, when the tension of certain muscles, hereafter to be described, is relaxed. The external ligament, being placed in such a manner that when the shell is closed its elastic fibres are doubled, always tends to recover a more extended position; whilst the internal cartilage, which is lodged in pits within the hinge-margin, is compressed by the closing of the shell, and of course assists in opening the valves, as soon as the pressure, under which it is confined, is reduced below its elastic force.



Fig. 303.—*Pholadomya alba*.

Each valve of the shell is usually of a very oblique, broadly-conical form, running up to an obtuse point, called the *umbo* or *beak* (Fig. 303). This is the first formed part of the shell; and as the principal additions to the size of the valves are made by the free margins of the mantle, it always retains its position close to the hinge. The shell often assumes a somewhat spiral appearance, especially at this part; and in some cases one or both valves exhibit the tendency to form a spire still more distinctly. The position of the umbones generally indicates that of the different parts of the shell in relation to those of the animal. Thus the umbones almost invariably reach the hinge-margin in front of the ligament (see Fig. 303); so that the portion of the shell towards which they tend is the anterior; the opposite portion the posterior region. The latter is generally the largest.

The interior of the shell is marked by impressions indicating the points of insertion of the muscles (Fig. 304). Of these, the principal are the impressions of the *adductor*



Fig. 304.—Right and left valves of *Amphidesma*, showing the impressions of the adductor muscles, the pallial line, and the pallial sinus.

muscles (Fig. 302, *a*), which are usually two in number, one placed in the posterior, the other in the anterior part of the shell, the former being generally the largest. These muscles are attached to the interior of both valves, which they close by their contraction. A linear impression, running from one of these impressions to the other, and called the *pallial line*, marks the position of the muscular margin of the mantle. It is generally more or less parallel to the margin of the shell; but in those species which possess retractile respiratory siphons, it is more or less indented at its posterior portion, forming what is called the *pallial sinus*; and the depth of this indentation indicates the length of the retractile siphons. The margins of the shells often fit each other exactly, so that when the valves are closed no space is left; but in many cases the valves are separated at one or both ends (Fig. 304). The shell is then said to gape.

When we look at the animal inclosed in this shell, we find that, although it certainly possesses no distinct head, its mouth is easily discernible (Fig. 302), and is always turned towards that part of the shell which we have described as the front. This being the anterior portion of the body, it follows that the mantle lobes and valves are placed upon its sides; whilst we shall find that the contrary prevails amongst the *Pallidibranchiata*, in which the valves are placed upon the upper and lower surfaces of the animal.

Of the greatest importance to the existence of the animal is the power of introducing a stream of water into the cavity of the mantle. This not only serves for the respiratory process, but also conveys to the creature those minute particles of organic matter of which its food consists. In the species with a closed mantle two apertures are seen at the posterior portion; of these, one serves for the admission, the other for the expulsion of

the water. In a great number of Mollusks the margins of the apertures are continued into tubes or siphons (Fig. 302), which in the burrowing species are often of great length (see Fig. 288). In some cases the two siphons are united so as to appear like a double tube. The branchiæ usually consist of a pair of laminae placed on each side of the body, and permeated from edge to edge by minute tubes. The walls of these tubes are composed of minutely reticulated blood-vessels; which, according to Messrs. Alder and Hancock, produce a texture resembling that of a sieve, through which the water passes into the tubes by which the gill-laminae are permeated. These communicate at the base of the gill with an anal chamber placed at the base of the exhalent siphon, through which the water, which has passed over the gills, and served for the purpose of respiration, is conveyed out of the body. The interior of the siphons, the surface of the gills, and that of the mantle, are all covered with cilia; and it is by the action of these microscopic organs that this important current of water is produced. But the sieve-like structure of the gill-laminae, assisted by the cilia with which they are clothed, has another office to perform besides that of respiration: they filter the water, collecting in grooves upon their surface all the minute floating particles which it contained. These are carried by the ciliary action to the edge of the branchial laminae, which is grooved, and thence conveyed to the mouth.*

The mouth is furnished with one or two pair of labial tentacles (Fig. 302), but is not armed with teeth. The intestine is convoluted, and passes through the heart. The anus opens into the base of the exhalent siphon. The liver is always voluminous. The foot, when present, is usually of a tongue-like form; it varies greatly in size, and is often wanting, especially in attached shells. In some cases it gives rise to a byssus, by which the animal fixes itself (see page 412).

Most of the bivalve *Mollusca* are furnished with auditory vesicles, inclosing otoliths. They are generally placed close to the ganglion of the foot. A few also possess eye-like organs, placed round the margins of the mantle. They are sometimes very numerous. The sexes are separate; the eggs are received amongst the branchiæ of the parent, and retained there until the young have attained a considerable development.

The *Lamellibranchiata* are all aquatic animals, and by far the greater part of them inhabit the sea. A few, however, are found in fresh water.

Divisions.—The classification of the bivalve *Mollusca*, here adopted, is founded partly upon that lately given by Dr. Gray, in the *Annals of Natural History* (May 1854). That gentleman divides the *Lamellibranchiate Mollusca* into two principal groups, or orders (sub-classes, Gray), distinguished by the presence or absence of respiratory siphons. In the *Asiphonata* (*Asiphonophora*, Gray), the mantle lobes are free for the greater part of their extent, or only united at the back so as to inclose a separate exhalent aperture. In the *Siphonata* (*Siphonophora*, Gray), on the contrary, the mantle lobes are more or less united; and the respiratory orifices are both distinctly separated, and frequently produced into long siphons.

ORDER I.—ASIPHONATA.

The *Asiphonata* order of bivalve *Mollusca* includes some of the most important of these animals; the common Oyster and the edible Mussel, as also the Pearl Oyster, belonging to it. The first is the type of the tribe *Ostracea*, characterized by having a

* For farther particulars, as to the structure and action of the branchiæ in the bivalve *Mollusca*, the reader may refer to the admirable memoir of Messrs. Alder and Hancock, in the *Annals and Mag. of Nat. Hist.* for Nov., 1851.

more or less orbicular shell, of which the valves are unequal. The animal reposes on, or adheres by, the more convex of its valves. The mantle of the animal is open throughout. The foot is sometimes entirely absent; when present, it is small, and usually furnished with a byssus. There is only a single adductor muscle.

The common Oyster (*Ostrea edulis*), which has always been a great favourite with epicures, both ancient and modern, is found in great abundance in many parts of our seas. They live in vast communities, called "oyster banks," each individual being attached, by its left or convex valve, to rocks, or other submarine objects. They spawn in May and June. The fry, called "spat" by the fishermen, consists of whitish gelatinous masses, in which the young Oysters may be discerned. These soon fix themselves by the shell to some object. They then grow rapidly; but they are said to occupy four years in attaining their full growth. The "native" Oysters are obtained from artificial oyster banks, formed by transporting the fry to shallow tanks, where

their food being present in great abundance, they thrive and acquire a finer flavour. Many other species of the genus *Ostrea* are eaten in different parts of the world. In some places Oysters grow in such abundance, attached to one another in masses, that they have been found as effectual in preventing the inroads of the sea as the coral reefs of the Pacific Islands. One of the most singular species is the *Ostrea crista-galli*, or Cock's-comb Oyster (Fig. 305), inhabiting the Indian Ocean.

The Oysters possess no foot; but in the singular genus *Anomia*, which is nearly allied to them, a small foot makes its appearance, and takes the form of a plug, which passes through an aperture in one of the valves, and thus attaches the creature.

In the well-known and often elegant *Pecten*, or Scallop-shells (Fig. 306), the foot

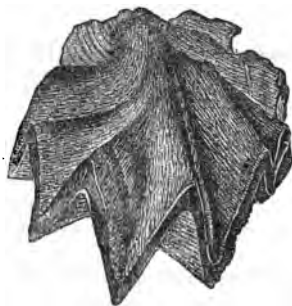


Fig. 305.—Cock's-comb Oyster.
(*Ostrea Crista-galli*.)



Fig. 306.—*Pecten opercularis*.



Fig. 307.—Pearl Oyster (*Meleagrina margaritifera*).

is distinct but small, and is sometimes furnished with a byssus. These animals are very abundant in some localities; and some of the larger species, such as the *Pecten*

maximus and *P. opercularis* (Fig. 306) of our own shores, are regarded as excellent eating. Another species was worn by pilgrims to the Holy Land; it has received the name of *Pecten Jacobaeus*, from its having been adopted in the middle ages as the distinctive cognisance of St. James of Spain. The free edge of the mantle in the *Pecten* is furnished with numerous bright ocelli.

The tribe of *Aviculacea* is rendered important by its including the Pearl Oyster amongst its members. The foot in this tribe is small, and produces a byssus, by which the animal attaches itself firmly to submarine objects. The mantle lobes are free; the shell usually oblique and somewhat triangular, with the valves unequal, and the hinge usually without teeth.

Most of the shells of this tribe are pearly in the interior; and as the true pearls are merely morbid growths, they may all produce pearls of various qualities. The formation of pearls is caused by the introduction of irritating substances, such as grains of sand, between the mantle and the shell. The irritation causes the animal to cover the obnoxious object with layers of pearl, which generally attach the foreign body to the interior of the shell. The Chinese produce pearls artificially by placing substances in the position just described; and we have seen some shells, to the interior of which small metal images were attached in this manner by the pearly secretion. The Pearl Oyster (*Meleagrina margaritifera*, Fig. 307) furnishes the finest pearls; and the shells are also imported in vast quantities; the inner layers, known as "mother of pearl," being used for a great number of ornamental purposes. The Pearl Oyster is found in various parts of the Indian and Pacific Oceans, at a depth of about twelve fathoms, whence they are taken by divers. The most celebrated fisheries, known to the ancients, were those of the Persian Gulf and Ceylon. The umbones of the *Aviculacea* are furnished with dilated lateral plates called *ears*; these are comparatively small in the Pearl Oyster, but in the curious "Hammer Oyster" (*Malleus vulgaris*, Fig. 308), an inhabitant of the Indian Ocean and the shores of Australia, these appendages attain a great length, and give the shell very much the appearance of a hammer or pickaxe. The *Pinnae*, already referred to (p. 412), also belong to this tribe.



Fig. 308.—Hammer Oyster (*Malleus vulgaris*).



Fig. 309.—*Arca auriculata*.

nished with a long row of similar teeth at the hinge (Fig. 309). The adductor muscles

are two in number, and the foot is large and often furnished with a byssus, and the mantle lobes are free all round. The *Trigeniacea*, which are closely allied to these, have the foot long and bent, serving for leaping, and the hinge furnished with but few teeth.

In the *Mytilacea*, of which the common Mussel (*Mytilus edulis*) is a well-known type, the mantle lobes are more or less united, having two siphonal apertures. The foot is furnished with a byssus, by which the animal attaches itself, and the shell is closed by two adductor muscles, of which the anterior is very small. The valves of the shell are equal, generally of an elongated oval form, covered with a thick epidermis, and usually pearly inside. The common Mussel, although greatly inferior to the Oyster, is consumed in great quantities as an article of food. The annual consumption in Edinburgh and Leith alone is calculated at 400 bushels, each of which is supposed to contain 1000 muscles. The consumption for baits is still more enormous; as many as between thirty and forty millions being employed in this manner in the Frith of Forth. At certain periods Mussels appear to have a deleterious effect upon persons eating them; but the cause of this has not yet been satisfactorily made out. Most of the *Mytilacea* conceal themselves by burrowing into various substances. The *Lithodemi* perforate solid rock, corals and shells. Some species make use of the byssus to spin themselves a sort of nest. They are generally marine; but the common Mussel may be found in fresh water; and a singular shell, the *Dreissena polymorpha*, which has recently been introduced into this country from the neighbourhood of the Black Sea, is always an inhabitant of fresh water.

The *Unionacea* are all inhabitants of fresh water. They have an equivalve shell, covered with a smooth epidermis, and lined with pearly matter. The margins of the mantle are free, for the greater part of their extent, united between the respiratory apertures. The foot is very large, and the adductor muscles are two in number. Several species of this tribe are found in this country; one of the commonest being the *Unio*



Fig. 310.—*Unio Pictorum*.

pictorum (Fig. 310), so called from its shell having been formerly much used by painters for holding their colours. All the species furnish pearls of inferior quality; and one species, the *U. margaritifera*, an inhabitant of the mountain streams of this country, is still collected for the sake of the pearls which it contains. The American species are very numerous.

ORDER II.—SIPHONATA.

The first tribe, the *Chamaea*, includes some of the largest of molluscous animals;

the animal of the *Tridacna gigas* (or Clam-shell), weighing sometimes as much as twenty pounds, whilst its valves occasionally attain the enormous weight of five hundred pounds. Smaller specimens are very common as garden ornaments. Another well known species is the *Hippopus maculatus* (Fig. 311), which is frequently employed in the manufacture of ornamental articles. The shell in the *Clam-shell* is very thick, usually attached, and the hinge has one or two teeth. The mantle is closed, with separate siphonal openings, but with the siphons obsolete, the foot very small; and there are two adductor muscles. In some fossil species the valves are spiral. The recent species inhabit the seas of warm climates.

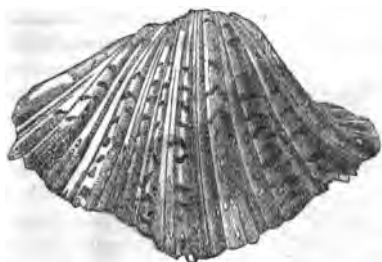


Fig. 311.—*Hippopus maculatus*.

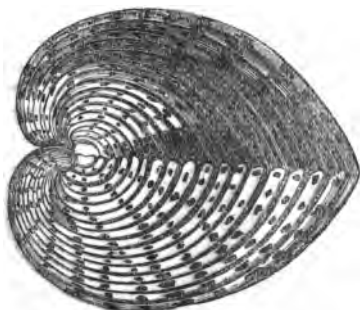


Fig. 312.—*Cardium Junonæ*.

The *Cardiacea* have a thick, closed, equivalve shell, with the umbones usually bent round, so that the shell, when seen from either extremity, presents a more or less cordate appearance (Fig. 312). The hinge teeth are strong, from one to three in each valve: and there are usually one or two smaller teeth on each side of the hinge. The mantle lobes are closed, the foot large and strong, and the siphons usually short, although in some species they are as long as in the following tribe, and the pallial line in these cases presents a slight sinuosity. The animal possesses two adductor muscles.

Many of these shells (of which the common Cockle, *Cardium edule*, is a well known example), are elegantly marked with radiating ribs, running from the umbones to the free margins; and in some cases the ribs are ornamented with spires of various and singular forms. They are generally active animals, springing to a considerable height by means of the strong, bent foot. They usually conceal themselves by burrowing in the sand or mud. In a few species the foot forms a creeping disc. The common Cockle is eaten, and in some localities forms an important article of food; but it has but little to recommend it.

The *Veneracea*, forming the first tribe of the bivalve Mollusks, with elongated siphons and a distinct pallial sinus, resemble the *Cardiacea* in the form of the shell and general structure. The foot is usually compressed, broad, and somewhat triangular, serving principally as an instrument for burrowing. The *Veneracea* are distinguished from the following tribe by having the respiratory siphons separate; at all events, for the greater part of their length. This group includes many exceedingly elegant shells, the exotic species especially being often adorned with a most charming variety of

colour. Some species are also ornamented with spines (Fig. 313). They generally conceal themselves by burrowing, sometimes into the sand and mud of the sea-bottom, and sometimes into solid rock. The principal agent in these operations is the foot.



Fig. 313.—*Cytherea spino-a*.

The *Pholadacea* are distinguished from the preceding tribe by having the siphonal tubes united through the whole or the greater part of their length (Fig. 314). Like the *Veneracea*, they are all burrowing animals, and the majority select hard substances, such as rock, wood, &c., for the construction of their burrows. The shells

are usually of an elongated form, gaping at one or both ends. They are closed by two

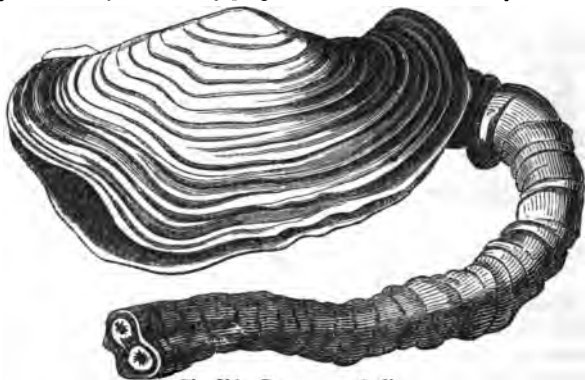


Fig. 314.—*Panopæa australis*.

adductor muscles. The foot is large and powerful, and the mantle is closed. The type of the group is the genus *Pholas*, specimens of which are common in the chalk rocks of the south of England. They are furnished with accessory plates on the back for the protection of the dorsal muscles. Another shell belonging to this tribe is the *Solen*, or Razor-shell, which burrows to a considerable depth in the sand. They are drawn from their burrows by means of a bent iron, and are said to be very good eating. One of the most celebrated species is the *Teredo navalis*, or Ship-worm, an animal which attains a length of one or two feet, and often does immense damage by burrowing into

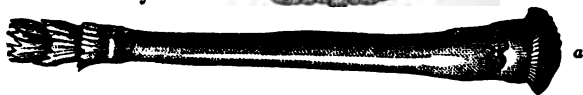
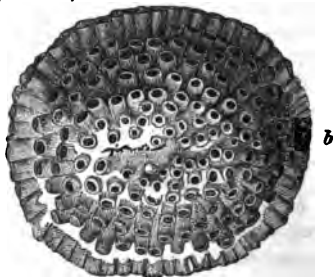


Fig. 315.—*Aspergillum vaginiferum*.
a, the shell complete; b, the perforated disc.

timber. In the years 1731 and 1732, it excited great alarm in Holland by boring into the piles which assist in protecting that country from the inroads of the sea. It is a soft, cylindrical, and somewhat worm-like animal, furnished with a pair of small shells at its anterior extremity. A still more singular animal, belonging to this tribe, is the *Aspergillum*, or Watering-pot shell (Fig. 315), which is inclosed in a calcareous tube, in the anterior part of which the two minute valves are imbedded. The anterior extremity of the tube is closed by a singular perforated disc (Fig. 315, *b*), and the opposite end is usually ornamented with several ruffle-like bands.

CLASS IV.—PALLIOBRANCHIATA.

General Characters.—The animals of this class are distinguished from the Lamellibranchiate *Mollusca* by the absence of any special branchial apparatus, the respiratory function being performed by the mantle, which is traversed by numerous blood-vessels. They are also characterized by the possession of a pair of long, ciliated, and usually spiral arms, the analogues of the labial tentacles of the ordinary bivalves. The action of the cilia with which these are clothed produces a current in the water, that carries the particles of food to the mouth, which is situated close to their base. From the presence of these organs the class is often termed *Brachiopoda*.

The valves, instead of being placed on each side of the body of the animal, are situated above and below it; so that they are called *dorsal* and *ventral*, instead of *right* and *left*, valves. The central valve is usually larger than the dorsal, and projects beyond it at the beak, where it is generally perforated to allow the passage of a muscular or tendinous peduncle, by which the animal attaches itself (Fig. 316 *a*). In some cases the peduncle is wanting, and the shell is then fixed by the beak. The connexion of the valves is effected by a pair of teeth, springing from the ventral valve, and locking into corresponding cavities in the dorsal valve. There is no ligament, and the valves of the shell are opened and closed by appropriate muscles.

The arms are frequently supported upon a calcareous framework or skeleton (Fig. 316 *b*), attached to the interior of the dorsal valve; this usually forms two loops, springing from the neighbourhood of the hinge. The arms appear to be extensible in some instances; but in others they are attached to the internal framework, and only the extremity is free.

The body of the animal only occupies a small portion of the cavity of the shell close to the hinge; it is inclosed within a strong membranous partition, in the centre of which the mouth is seen. The intestine is convoluted, and the liver is large and granular. All the *Palliobranchiata* appear to possess two hearts, each composed of an auricle and a ventricle, situated in the neighbourhood of the œsophagus; they are also furnished with a complex system of vessels, which conveys the blood to the organs of the body, and to the mantle, where it is exposed to the influence of the water.

The structure of the shell is very peculiar. It consists of flattened prismatic cells, arranged in an oblique direction as regards the surfaces of the shell; the substance of the shell is traversed by small canals, through which little processes of the outer layer of the mantle pass.

These animals are all marine; they are found attached by the peduncle, which

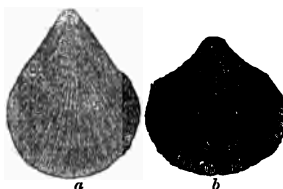


Fig. 316.—*Terebratula australis*.
a, shell closed, showing aperture
b, dorsal valve, with framework.

passes through the aperture in the ventral valve, suspended from rocks, corals, and other submarine objects. The fossil species are exceedingly numerous, especially in the older strata, in some of which they are the principal representatives of the Molluscan type of structure.

Divisions.—The greater number of the species of this class are fossil; but a good many are still found in our seas. We may distinguish three principal groups or families. In the first, the *Cranida*, the ventral valve of the shell is usually adherent, without the intervention of a peduncle, and the hinge is destitute of teeth. The interior of the valves has a broad granulated border, and the disc is marked with four deep muscular impressions (Fig. 317).



Fig. 317.—Crania per-
sonata.

In the second group, the *Terebratulida*, the beak of the ventral valve is pierced with a hole for the passage of the peduncle (Fig. 316), and the valves are united by a hinge. This family includes the greater part of the species, both of recent and fossil *Paliobranchiata*.

In the third group, that of the *Lingulide*, the animal is attached by a peduncle; but this, instead of passing through an aperture in one of the valves, issues from the interior of the shell between the umbones. The valves are nearly equal, horny, and



Fig. 318.—*Lingula anatina*.

flexible; and the peduncle is very long. The best known species, the *Lingula anatina* (Fig. 318), is found in the Eastern Ocean.

CLASS V.—PTEROPODA.

General Characters.—The singular little animals included in this group present many points of resemblance with those of the following class, especially in their young state. Hence several naturalists have united these animals with the *Gasteropoda* in a single class, denominated *Cephalophora*, or *head-bearers*; but as the Pteropods differ greatly from the other Cephaloporous *Mollusca*, we have preferred leaving them as an independent group.

They are all of small size, and furnished with a pair of broad flattened fins at the sides of the head, by means of which they swim with tolerable rapidity through the open sea. They are inhabitants of the ocean, and rarely venture near the shore, except when driven from their favourite haunts by high winds; on the high sea they often abound in such profusion as to colour the surface for miles together.

The claim of many of these animals to the distinction of possessing a head, is perhaps a debatable point; for a considerable number present scarcely any traces either of eyes or tentacles on the anterior extremity of the body. In other cases, however, these organs, especially the latter, are perceptible. The ganglia are placed below the oesophagus, the supra-oesophageal ganglia being represented by a slender ring; they

all possess auditory vesicles, containing otoliths. The mouth is generally unarmed, sometimes furnished with sucking tentacles, but the oesophagus is muscular, and the tongue frequently armed with teeth. The intestine is convoluted, and the anus usually opens on the right side near the neck. The circulatory system is very incomplete; the heart is composed of two cavities, and the respiratory organs are either external or inclosed within a cavity of the mantle. The foot, which is such an important organ in the following class, is here either entirely wanting, or, if present, forms only a little lobe between the bases of the fins.

Divisions.—We distinguish two orders of *Pteropoda*, characterised by the presence or absence of a shell.

ORDER I.—GYMNOSOMATA.

The animals of this order are distinguished by the absence of a shell, and the distinct separation of the head from the body. The skin is of a firmer texture than in the following order, where it is protected by a shell. The species of the genus *Chio* (Fig. 319), belonging to this order, are found principally in the Arctic and Antarctic Seas, where they occur in prodigious numbers. So great, in fact, is their abundance, that although they do not exceed an inch in length, they furnish one of the principal sources of the nourishment of the gigantic Whales. They are usually of a beautiful blue or violet colour, tinged with red.

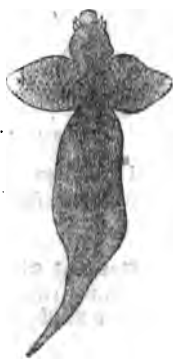


Fig. 319.—*Chio australis*.

ORDER II.—THECOSOMATA.

The *Thecosomata* are always inclosed in a shell, which is usually very delicate, and of a glassy transparency. It varies greatly in shape, its simplest form being triangular

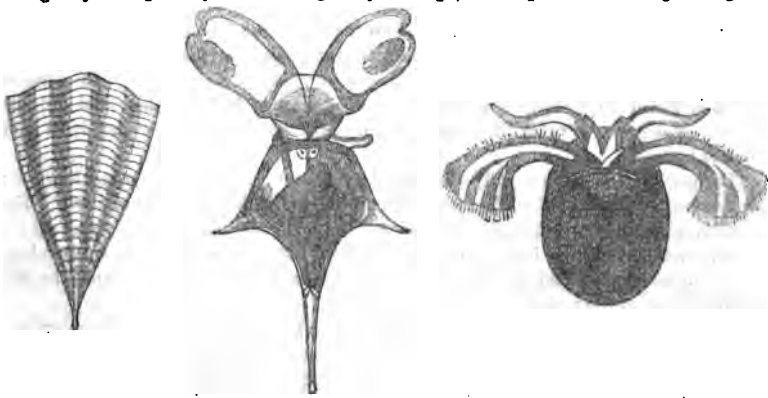


Fig. 320.

Fig. 321.

Fig. 322.

Fig. 320.—Shell of *Cleodora pyramidata*.

Fig. 321.—*Hyales*.

Fig. 322.—*Eurybia Gaudichaudii*.

(Fig. 320), or rather pyramidal; but the basal portion is often somewhat globular, and

adorned with two or three projecting angles or spines (Fig. 321). The head is less distinctly separated from the body than in the *Gymnosomata*; the foot is obsolete, and the respiratory organs are inclosed within a cavity of the mantle.

Some of the most beautiful and best known species belong to the genus *Hyalea* (Fig. 321), so called from the glassy texture of their shells. In *Eurybia* (Fig. 322) the animal and shell are sub-globular in shape, without points proceeding from the latter. In a few genera the shells acquire a spiral form; thus in *Limacina* (Fig. 323), a genus of minute Mollusks found in the Arctic and Antarctic Seas, the shell resembles that of a little Nautilus in its form; whilst in *Spirialia*, it forms a little pointed spire, furnished with a minute glassy operculum.



Fig. 323.—*Limacina rostralis*.

CLASS VI.—GASTEROPODA.

General Characters.—The most striking characteristic of the *Gasteropoda* consists in the structure of the locomotive organ. This, which is well shown in the common Snails, consists of a broad, muscular, disc-like foot, attached to the ventral surface (whence the name), upon which the animal creeps slowly along with a sort of gliding motion. This form of foot is presented by nearly all the animals referred to this class; although, in a few species, it is so greatly modified, that at the first glance it would not be taken for the same organ.

The head is always distinct, usually furnished with tentacles and eyes. The opening of the mouth is placed in its lower surface; it is often furnished with a protrusible proboscis, and armed with one or two teeth or jaws inserted in its upper part. The lower part of the mouth and oesophagus is occupied by the tongue, a long ribbon-shaped organ, sometimes longer than the whole body, covered on its upper surface with an immense number of minute silicious teeth, which are employed, with the assistance of the upper jaws, in dividing the food. The arrangement and form of these lingual teeth, as they are called, are very constant in the different groups; they have been lately employed as valuable characters in the classification of these animals. The lingual ribbon is rolled up posteriorly; and it is supposed that it is unrolled and brought forward by degrees, in order that new teeth may take the place of those that have been abraded by use.

The intestinal canal is usually simple and membranous. In some species, however, the stomach has thickened walls, furnished internally with horny ridges or teeth. The intestine winds amongst the other viscera, and the anus is situated on the right side of the anterior part of the body. The liver is very voluminous, and usually envelops the other intestines; and nearly all the *Gasteropoda* possess salivary glands in the neighbourhood of the mouth.

Respiration is generally effected by means of branchiæ, placed sometimes on the surface of the body, but more commonly in a special cavity in the back of the mantle, the aperture of which is situated over the neck. The margins of this aperture are often produced into a siphon, which projects over the head of the animal; the water, after traversing the gills, passes off by a separate aperture, situated on the right side of the body: and this is also siphonate in some instances. The branchiæ are plumose or branched organs. As a general rule, only those of the right side are developed; but in

some cases the animals are symmetrical in this respect. In the Land-snails, and a few fresh-water Mollusks, the respiratory function is performed by a pulmonary sac,

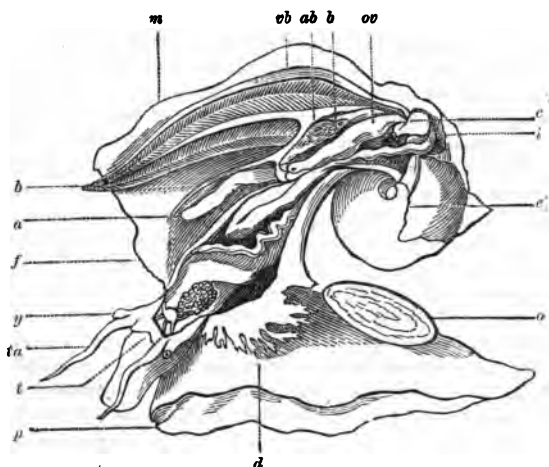


Fig. 324.—Anatomy of *Turbo Pica*.

p, foot; *o*, operculum; *t*, proboscis; *ta*, tentacula; *y*, eyes; *m*, mantle opened longitudinally, to show the disposition of the respiratory cavity; *f*, anterior border of the mantle, which, in its natural position, covers the back of the animal, leaving a wide slit by which the water enters the branchial cavity; *b*, the gills; *eb*, branchial vein, returning to the heart; *c*, branchial artery; *a*, anus; *s*, intestine; *e*, stomach and liver; *ov*, oviduct. On the upper side of the neck are seen the cephalic ganglion, and the salivary glands; and at *d* is shown a fringed membrane, which forms the lower border of the left side of the opening that leads to the respiratory cavities.

hollowed out in the right side of the body near the neck, and opening externally at that point by an aperture which the animal can open or close at pleasure.

The heart consists of two chambers, and is generally placed in the neighbourhood of the branchiæ. The blood leaves the heart by a large artery, which generally soon divides into two branches, one running to the head and anterior part of the body, the other to the posterior organs. On its return the blood does not appear to be confined within true veins; it flows through the interstices of the organs, and is at last collected into particular canals, by which it is conveyed to the respiratory organs, whence it passes again to the heart.

The nervous system varies greatly in development, and in the arrangement of its parts; but in all, the centre is formed by an œsophageal ring or collar, composed of several ganglia united by nervous filaments. The supra-œsophageal ganglia are sometimes distinct, sometimes fused into a mass; they always give off the nerves of the organs of sensation situated on the head. The ganglia which supply nerves to the foot, the mantle, the intestines and other organs of the body, are connected, by means of nervous filaments, with the ganglia placed below the œsophagus. The organs of the senses consist of tentacles of very various forms: of a pair of eyes, placed sometimes on the head itself, sometimes on the sides of the tentacles, or supported upon separate

stalks; and of a pair of auditory vesicles, containing otoliths, generally placed near the base of the tentacles, and either immediately in contact with the brain, or connected with it by a short nerve. No special organs of smell or taste have been detected in the *Gastropoda*, although we may infer, from the discrimination exercised by the animals in the choice of their food, that they are not destitute of these senses.

The general form of the body, in the *Gastropoda*, is very characteristic of the class. From the great preponderance of one side of the body over the other, the whole acquires, during growth, a spiral form; and it is only in some naked species, and in those which have branchiæ equally developed on both sides, that we find the body symmetrical. The shell with which the animals are furnished, and which, as in the other *Mollusca*, is secreted by the edge of the mantle, partakes of this form. It is almost always composed of a single piece (univalve), and usually forms a conical tube, twisted spirally (Fig. 289). This tube, however, is rarely perfect, the inner wall of each whorl as the convolutions of the spire are termed being usually formed by the surface of the preceding whorl, which the animal covers with a thin coating of shelly matter. In the majority of these shells the spire takes an oblique direction, so that the shell has a pointed apex, and goes on increasing in breadth towards the lower extremity (Fig. 325). In some, however, the whorls are rolled one upon another in the same plane, producing a discoid shell (Fig. 326); and we meet with every possible gradation of form between the extremes of obliquity and flatness. In *Scalaria*, the tube of the shell is perfect,



Fig. 325.—*Pirena*.

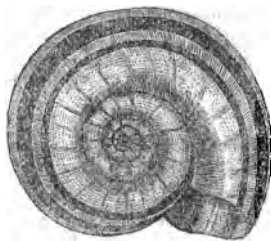


Fig. 326.—*Ampullaria*.

although the whorls are closely applied to each other; but in *Vermetus* and some others, the shell forms a simple more or less contorted tube. The same thing occurs in monstrous varieties of regularly spiral shells; and a few species which inhabit a spiral shell until they attain a certain size, afterwards add to it by forming a straight tube of the diameter of the aperture. As the right side of the *Gastropoda* is almost always the largest, the convexity of the spire is, of course, turned in this direction, and the

shells follow the same rule. These normal shells are called *dextral*; in a few species, however, and in some monstrosities of dextral species, the spire turns in the opposite direction: these are called *sinistral* shells. In the truly spiral shells, the progressive winding of the tube produces a mere or less distinct central axis, or pillar, called the *columnella*, which runs from the base to the apex of the shell, and forms the inner margin of the aperture from which the animal protrudes when in motion. This pillar is usually hollow, and terminates at the base of the shell by a small opening, called the *umbilicus*. The margins of the aperture are called the *lips*; the outer lip (*labrum*) forms the convexity of the shell; the inner lip (*labium*) is usually formed by the *columnella*, and is hence denominated the *columnellar lip*. The two lips are sometimes com-

tinuous, but more commonly separated by a notch, which is often, in the siphonated species, produced into a canal. The junction of the outer lip with the preceding whorl is also frequently marked with a notch, for the reception of the excurrent siphon. The outer lip is frequently reflexed, or furnished with spines or tubercles; its margin is sometimes turned inwards, and both lips are not unfrequently furnished with teeth or other projections on the inside. The last whorl of the shell is called the *body whorl*, from its receiving the body of the animal when retracted. The remaining whorls form the *spire*; and the impressed line which separates the whorls is the *suture*.

A great number of the *Gasteropoda* close the aperture of their shell with a small horny or calcareous plate, called the *operculum*, which is attached to the hinder part of the foot, and is drawn into the mouth of the shell by the contraction of the animal. It is seen in the young animal whilst still in the egg; and this forms the *nucleus* of all subsequent growth. It varies greatly in its form, being sometimes composed of concentric layers, sometimes spiral, sometimes oval or sub-circular, with the nucleus placed



Fig. 328.—Forms of opercula. *a*, spiral (*Turbo*); *b*, lamellar, with marginal nucleus (*Murex*); *c*, appendiculate (*Nerita*).

at one side, or at the extremity; sometimes irregular in form, or furnished with appendages (see Fig. 328).

Most of the *Gasteropoda* are strictly oviparous animals; but a few are ovo-viviparous; the eggs being retained in the oviducts until the exclusion of the young, and even until these have attained a considerable development. The sexes are generally on separate individuals, but a considerable number are hermaphrodites; these, however, require mutual impregnation to fertilize the ova. The orifices of the generative organs are usually situated on the right side of the body, in the neighbourhood of the anus. The mode in which the ova are deposited, and their arrangement, have already been briefly referred to (see page 416). The young Mollusk is always provided with a shell whilst in the egg; this, however, is cast off, soon after hatching, by most of the naked species. The young of the air-breathing species resemble their parents in every respect except size; but those of the branchiferous species are furnished with a pair of fin-like expansions, resembling those of the *Pteropoda*, by means of which they swim freely through the water.

Divisions.—The *Gasteropoda* may be divided into two sub-classes, the *Heteropoda* and the *Gasteropoda proper*; the former including only a single order, whilst the latter are divided into two great orders, called *Branchifera* and *Pulmonifera*, from the nature of their respective respiratory organs.

SUB-CLASS AND ORDER I.—HETEROPODA.

General Characters.—The animals of this group, the *Nucleobranchiata* of some authors, are all inhabitants of the ocean, where they swim about rapidly, the whole structure of their bodies being adapted particularly to this mode of existence. The foot, when present, is converted into a broad, flattened, fin-like organ (Fig. 328), furnished

with a small sucker, by which the animals adhere to floating sea-weeds. The whole body is usually compressed; and it is by the fin-like action of the tail that the creatures swim. The head is distinct, and usually furnished with a pair of tentacles and

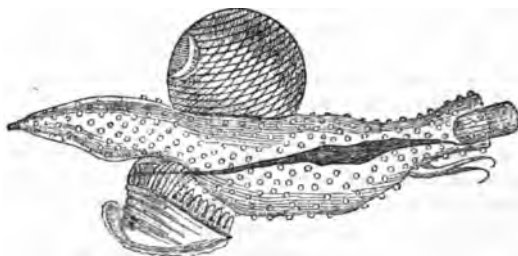


Fig. 329.—Carinaria.

eyes; the mouth is generally furnished with a long proboscis. In the typical forms, the intestines, with the heart and generative organs, are collected into a mass on the back of the animal; this is inclosed in a shell, round the interior of which the comb-like branchiæ are situated.

The animals are usually of a transparent gelatinous texture; they swim with the back downwards, and appear to feed upon minute marine animals.

Divisions.—In the *Atlantida* (Fig. 330), the shell is spiral, and large enough to contain the whole animal when contracted; and the gills are contained in a regular branchial cavity. They often possess a delicate operculum.



Fig. 330.—Atlanta Kerandreni.

The *Firolide* are either entirely naked, or furnished with a small, conical, keeled shell, which incloses the intestinal nucleus (Fig. 329). The *Firolæ* are destitute of a shell.

The *Sagittide* form a third small family, whose title to this position is, however, by no means certain. They are little, fish-like animals, furnished with one or two pairs of fin-like organs on the body, and with a broad and usually bilobed caudal fin (Fig. 331). The head is distinct, and the mouth armed with several



Fig. 331.—Sagitta.

pairs of lateral hook-like jaws. They are of small size, and swim with great rapidity. They have hitherto been found principally in the North Sea and in the Mediterranean. The name of *Sagitta*, given to these animals, refers to their arrow-like appearance.

SUB-CLASS II.—GASTEROPODA PROPER.

In the true *Gasteropoda*, which exhibit the structure of the foot, and the general structure of the body, already described as characteristic of the class, we distinguish two great orders,—the *Branchifera*, furnished with gills, and the *Pulmonifera*, which respire by pulmonary sacs. Besides this important difference in structure, the branchiferous *Gasteropoda* pass through a distinct larval state; usually issuing from the egg in a very different form from that they are ultimately to assume, as already described at page 439. The pulmoniferous species undergo no metamorphosis.

ORDER II.—BRANCHIFERA.

The general characters of this group are given above. It is divided into two sub-orders, characterized by the position of the branchiæ.

SUB-ORDER I.—OPISTHOBANCHIATA.

General Characters.—In the animals forming this sub-order, the branchiæ are not generally inclosed within a cavity of the mantle, but more or less exposed on the back or sides of the animal, generally towards the posterior portion; and the auricle of the heart, which receives the blood from the gills, is placed behind the ventricle. All these animals are hermaphrodites; few of them are inclosed in a shell; some have an internal shell, but the majority are naked.

Divisions.—This sub-order includes two principal groups. In the first, the *Tectibranchiata*, the animals are generally furnished with a shell, and the branchiæ are covered either by the shell or the mantle. The *Bullidæ*, or bubble-shells, have a delicate cylindrical or globose shell, which is more or less inclosed within the mantle; the head is flat, with broad tentacular lobes; the foot is large, and often furnished with lateral lobes, which the animal is said to use in swimming; the gill is single, placed on the right side of the back, and concealed by the shell. They are carnivorous in their habits, and are furnished with a gizzard, in the walls of which several calcareous plates are imbedded.

In the *Aplysiadæ* the shell is either absent or rudimentary. The animal is slug-like in its form; the head is distinct, and furnished with tentacles and eyes, and the sides of the mantle are very large, and reflected upwards, so as to cover the back and branchial plume. The tentacles are turned back like ears; whence the name of *sea-hares* commonly applied to these animals. They live upon sea-weeds, from which they derive their principal nourishment, although they also feed upon animal substances. When alarmed or molested, they emit a violet or reddish fluid from the mantle, which was long supposed to be of a poisonous nature; although, according to recent observations, it is quite harmless.

The *Pleurobranchidæ* are also usually furnished with a shell, which, however, is often concealed by the mantle; the foot is usually very large, and the feather-like gill is concealed between a fold of the mantle and the foot. The shell is sometimes limpet-like in its shape; one of them, inhabiting the Indian and Chinese Seas, is commonly known as the *Umbrella shell*. The *Phyllididæ* are nearly allied to these, but have no shell, and the branchiæ are placed on both sides of the body, beneath a fold of the mantle.

In the second great group, the *Nudibranchiata*, the animals are shell-less, and the branchiæ are placed on the back or along the sides of the body, without any covering. These animals are also hermaphrodites. These elegant and delicate little creatures, which are often adorned with the most pleasing colours, are generally found near the coasts, crawling upon sea-weeds. They are very carnivorous in their habits, feeding principally upon zoophytes. A most admirable monograph of the British species, by Messrs. Alder and Hancock, has been published by the Ray Society. The Nudibranchiate Mollusks are distributed into three families. In the *Eolididæ*, the branchiæ are arranged along each side of the back, which is also furnished with peculiar appendages, into which processes of the liver and stomach pass, and the tentacles are not retractile.

These animals generally resemble little slugs, with tufts of filaments along the sides



Fig. 332.—*Æolis*.

(Fig. 332); but some species present a very singular appearance, having the body very slender, and the gill tufts supported at the extremities of lateral foot-stalks (Fig. 333). The *Tritoniidae* often resemble the preceding in appearance, but they are destitute of the coecal prolongations of the intestines, and have the tentacles sheathed and retractile. The *Dorida* are generally of a broader form and larger size than the animals of the preceding families, from which they are distinguished by

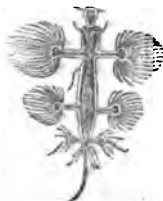


Fig. 333.—*Glaucus Forsteri*.



Fig. 334.—*Doris*.

having the branchiae placed in a circle on the back, generally towards the hinder parts. The branchiae are elegant, arborescent organs; the foot is much smaller than the mantle.

SUB-ORDER II.—PROSOBRANCHIATA.

General Characters.—This sub-order is far more extensive than the preceding, and the characters by which it is circumscribed are far more distinct. All the animals referred to this group possess a shell, within which they can usually retract themselves entirely at pleasure, and this is almost always of a spiral form; the mantle forms an arched chamber, immediately over the neck, in which the branchiae are situated, together with the orifices of the alimentary and generative organs; and, as a necessary consequence of this anterior position of the gills, the blood flows back towards the heart, and the auricle of the latter organ is placed in front of the ventricle. The sexes are almost always distinct, and nearly all the species are marine.

Divisions.—The *Prosobranchiata* may be divided into three principal groups. In the first, the *Cirrhhobranchiata*, including only a single family, the *Dentaliidae*, or tooth-shells, the animal is so anomalous in its form that it was placed by Cuvier and other observers amongst the *Annélides*. The shell is tubular, gradually tapering from one end to the other, and gently curved throughout its whole length, so as to have the appearance of a miniature Elephant's tusk (Fig. 336); hence the commonest species (*Dentalium entalis*) is popularly denominated the Elephant's tooth. It has an aperture at each end, that at the narrower extremity being very small. The animal (Fig. 335) inhabiting this shell is of a cylindrical form, inclosed in a sac-like mantle, from the anterior extremity of which the tip of the foot is protruded. The head is situated at the middle



Fig. 335.—Animal of *Dentalium*, with the anterior part of the mantle removed.

a, foot; b, branchiae, with the head between them; c, anal tubercle.

of the upper part of the body, and on each side of it are the symmetrical cirrus-like branchiæ. The anus opens at the posterior part of the body. The *Dentaliids* are



Fig. 336.—*Dentalium*, with foot protruded.

carnivorous, feeding upon minute marine animals. They live in sand or mud, in which they bury themselves by means of the foot. A good many species are known, of which several inhabit the British seas.

In the *Cyclabrenchiata* the branchiæ are unusually placed all round the body, in the space between the margin of the foot and the mantle, although in some species they are situated in a cavity over the neck. The *Patellids*, or Limpets, may be considered as the types of this group; they are inclosed in a conical shell (Fig. 337), the interior of



Fig. 337.—Limpet (*Patella*).

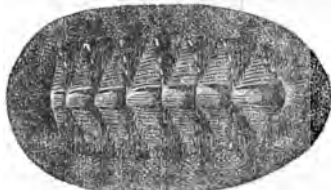


Fig. 338.—Chiton.

which is entirely occupied by the animal; the foot is very large, and by means of it the Limpet fixes its little residence so firmly to rocks and other objects, that it is not to be detached without great difficulty. They feed on vegetable matters, and occur in great abundance in many situations; they are often used as food by the poorer classes, and are also collected in great numbers for baits. The *Chitonids* resemble the Limpets in the situation of their branchiæ; but these organs only run round the posterior part of the body. The shell in the *Chitons* (Fig. 338) is composed of eight calcareous plates, overlapping one another at the edges, and united by a strong leathery mantle, which forms a border all round the shell. They adhere to rocks like the Limpets. Our British species are all small; but many tropical species attain a considerable size, and of these the muscular foot is often eaten by the natives of the countries in which they occur.

The *Pectinibranchiata* exhibit the characters of the sub-order in their greatest perfection; the branchiæ are usually single, and inclosed in a cavity over the neck of the animal.

The *Calyptroids* have a Limpet-like shell, which is usually somewhat spiral at the apex, and frequently furnished with a sort of shelf of shelly matter in the interior. They appear to pass a perfectly sedentary life, attached to stones and rocks, to the irregularities in the surface of which their shells usually adapt themselves. In the *Haliotids* the spiral conformation of the shell goes a little further, and there is a perforation or notch for the passage of the anal siphon at the posterior margin. In the

common Ear-shells these perforations are arranged in a row along the back of the shell. The animal has a short muzzle and two branchial plumes. The *Fissurellidae*, which are nearly allied to these, have a shell closely resembling that of the Limpet in form, but perforated at the apex for the passage of the anal current.

The family *Ianthinidae* contains a few species of oceanic *Mollusca*, which possess a shell almost exactly resembling that of a common Land-snail; it is of a delicate texture, deep violet at the base, and with the spire white. The animal has two branchial plumes, a muzzle-shaped head, with tentacles, but without eyes, and a very small foot, which, however, secretes a remarkable structure, considered to be the analogue of the operculum. It consists of a large raft, composed of numerous horny vesicles filled with air, to the under surface of which the animal attaches its eggs, and thus floats about at the surface of the water, being supported by the buoyancy of the float. The *Ianthinidae* are carnivorous animals; they often occur in vast numbers in the Atlantic, and are sometimes driven by stress of weather upon the southern shores of our island.

In the *Naticidae* the shell, which is globular, composed of few whorls, and opening with an entire aperture, is partially inclosed in the mantle; the foot is very large, furnished in front with a broad lobe, which conceals the head, and behind which the tentacles rise. The mouth has a long retractile proboscis, and the animals are carnivorous in their habits. They are all marine. In the *Turbinidae*, the shell is more or less conical or pyramidal, generally with a distinct umbilicus (Fig. 289), and the aperture is closed by a spiral operculum (Fig. 328 a). The animal has a short muzzle; the tentacles are long and slender, with the eyes supported upon short footstalks at their bases; the sides are frequently furnished with tentacular cirri, and the branchial plume is single. The shells are generally pearly in the interior. These animals are very numerous, and widely distributed; they are all marine, and feed on vegetable substances. The pyramidal *Trochi*, or top-shells, are very common on all our coasts.

Nearly allied to the *Turbinidae* are the *Neritidae*, a small family of Mollusks, furnished with a thick and somewhat globose shell, with a small spire (Fig. 339), and the margins of the aperture turned in and toothed. The columellar lip has a projecting plate, behind which the inner walls of the spire are removed; so that the interior of the shell presents a simple cavity. The animals have a broad foot, a broad muzzle, and very long tentacles, at the base of which the eyes are placed upon short footstalks. Most of them are marine; but one genus, the *Neritina*, inhabits fresh

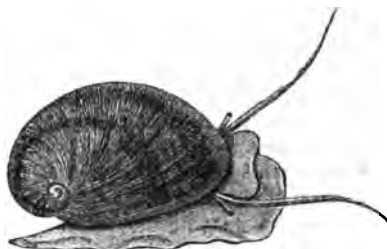


Fig. 339.—*Nerita polita*.

water. The mouth of the shell is closed by an appendiculate operculum (Fig. 328 a).

In the large family of *Turritellidae*, the shell exhibits a great variety of form, being sometimes semi-globular, with a short spire, or even discoid, and sometimes much elongated and tapering gradually to the apex. The aperture is entire, and closed by an operculum, which is usually horny and spiral. The animal has long slender tentacles, which usually bear the eyes on their outer surface, at or near the base. The head is generally short and broad, without a proboscis, and the rows of teeth on the lingual ribbon are arranged in rows of seven.

Most of these animals are marine, but several genera are found in fresh water; of these the *Paludina vivipara*, which is common in Britain, is, as its name implies, viviparous, the young being hatched and retained within the oviduct until they have attained a considerable development. The *Ampullaria* are furnished with a long siphon. They also inhabit fresh waters, and often possess beautiful shells (Fig. 326). The common Periwinkle (*Littorina littorea*) also belongs to this family. In the genus *Vermetus* and its allies, the whorls of the spire are separated for the greater part of their length, giving the shell the appearance of a twisted tube; from this circumstance they were referred to the Annelides before the animal was known.

The *Cerithiidae* have an elongated spiral shell, with the outer margin of the aperture more or less dilated, and the base produced into a slight siphonal canal (Fig. 340). The aperture is closed by a horny, spiral operculum. The animal has a short muzzle, and long, slender tentacles, having the eyes on the outside, at a short distance from the base. In the *Aporrhais pes pelecani*, the margin of the aperture is much dilated, and the siphonal canal very distinct, forming a transition to the next family.

The animals of the following families are all carnivorous in their habits; they have spiral shells, with the aperture notched, or produced into a canal at the anterior extremity. They are all furnished with a retractile proboscis.



Fig. 340.—*Cerithium granulosum*.

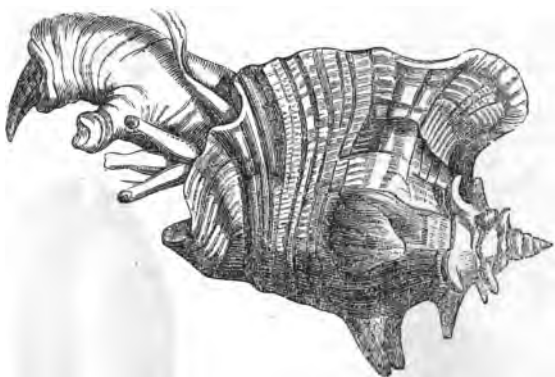


Fig. 341.—*Strombus*.

The *Strombidae* have the outer lip of the shell much expanded, and notched in the neighbourhood of the siphonal canal; the operculum is elongated, and toothed along the outer margin. The foot is narrow, and ill adapted for creeping; but the animals are active, and leap well. The proboscis is long and thick; the eyes large, and supported upon long stout footstalks, from the sides of which the short tentacles take their rise. The operculum is borne upon a curious process of the foot (see Fig. 341). The dilated margin of the aperture is often singularly toothed, or furnished with large spines, as in the well-known Scorpion-shells (*Pteroceras*). The *Strombidae* feed principally upon carrion, and many of them are of large size.

In the vast family of *Muricea*, the outer margin of the shell is not notched near the canal; the canal itself is sometimes produced in a line with the axis of the shell, and sometimes reflexed. The animal has a long proboscis, with which it bores through the shells of other *Mollusca*, shortish tentacles, which sometimes bear the eyes, and a broad foot adapted for crawling. The *Muricea* are all marine, predatory animals. Their shells are generally ornamented with spines (Fig. 292), which often assume the most singular forms. Many of the exotic species are of exceedingly beautiful colours, and some are of considerable value. The large Helmet-shells (*Cassia*) are much employed in the manufacture of cameos; some of the species, such as the Whelks (*Buccinum*), are eaten; and it is supposed that the celebrated purple dye of the ancients was obtained from some Mollusk belonging to this family. In the nearly-allied family, *Volutida*, which also contains many elegantly-marked shells (Fig. 342), the outer margin of the aperture is not reflexed, the canal is reduced to a notch, and the inner lip is plaited. The shell is more or less enveloped in the mantle; the foot is broad, and bears no operculum. These animals resemble the *Muricea* in their habits; they are found principally in the tropical seas.

The beautiful animals, forming the family *Conidae*, are nearly allied to the preceding. Their shells are of a reversed conical form, becoming broader towards the apex, the spire being often quite flat; the aperture is long and narrow, and the operculum is very small.

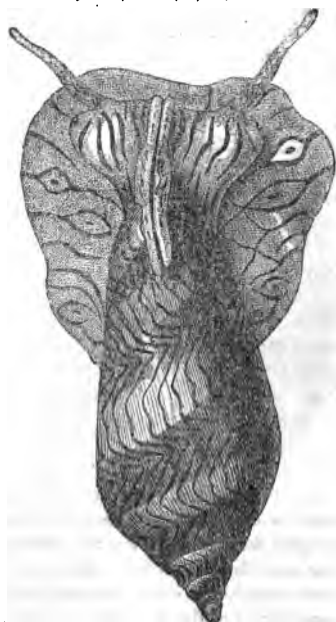


Fig. 342.—*Voluta undulata*.

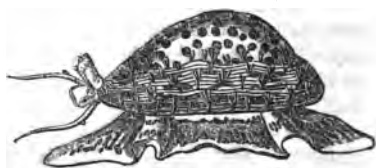


Fig. 343.—*Cyprea tigris*.



Fig. 344.—Adult *Cyprea*.

The teeth on the lingual ribbon are arranged in pairs. These are exceedingly predatory animals, which are said to bite severely when touched. Many of the shells are exceed

ingly elegant, and some of the rare species have realised almost fabulous prices. In the *Cypræide*, one species of which, the *Cypræa tigris* (Fig. 343), is so common that it must be familiar to every one, the shell presents a very different appearance at different ages. In the young state it is distinctly spiral, with a plain outer lip; but as it increases in age, the whorls are brought into the same plane, and in course of time the spire is usually entirely concealed. At the same time the outer lip becomes thickened, turned in and dentated, producing the appearance shown at Fig. 344. The animal greatly resembles that of the *Volutide*; but the mantle usually covers nearly the whole of the shell, and deposits upon its surface the enamel which contributes so much to the beautiful appearance of these shells. The *Cypræide* are found in great abundance in the seas of the tropical parts of the world; many of them are much sought after by collectors, and several of the smaller species are applied to ornamental purposes by the natives of the countries where they are found. The *Cypræa moneta*, or Money-cowry, stands in lieu of coin with the negroes of Western Africa; and other species are made use of in the same way amongst uncivilized people.

ORDER, III.—PULMONIFERA.

The Pulmoniferous, or air-breathing *Mollusca*, including the land snails and their allies, are distinguished, as we have already stated, not only by the structure of their respiratory organs, but also by their young being hatched in a form closely resembling that of the parents.

Divisions.—They are divided into two great groups, the *operculated* and the *inoperculated Pulmonifera*.

The operculated species form only a single family, the *Cyclostomide*, composed of snail-like animals, with thin spiral shells, of which the margins are usually reflexed all round. They have only two tentacles, with the eyes inserted in their basal portion. The *Cyclostomide*, also, differ from the majority of the *Pulmonifera*, in being unisexual.

Of the inoperculated section, the common land snails may be taken as the type. They form the family *Helicidæ*, characterised by their ample external shell, within which the animal can retract itself entirely, and by their possession of four tentacles, upon the summits of the longest of which the eyes are situated. This is a very extensive family of herbivorous Mollusks, which are found in great abundance in all parts of the world.

The *Limacide*, or Slugs, resemble the snails in the form of the body, in the number and structure of the tentacles, and in their habits; but their shell is very small or rudimentary, and usually concealed in the interior of the mantle. The little family *Oncidiidæ* consists of small, slug-like animals (Fig. 345), covered with a leathery mantle, but quite destitute of a shell. The head is furnished with either two or four tentacles. They are generally found in marshy place upon aquatic plants; but some of them inhabit the sea-coast, within reach of the waves. They are mostly inhabitants of warm climates.

In the *Limnæide*, or Pond Snails (Fig. 7), the shell is ample; but the tentacles are only two in number, with the eyes sessile near their bases. The shell is thin and horny, with the aperture simple; whilst in the *Auriculidæ*, which frequently inhabit the sea-shore, the shell is much stronger, with the margins of the aperture thickened and notched. In these the tentacles are also two; but the eyes are situated on the head.



Fig. 345.—*Oncidium*.

CLASS VII.—CEPHALOPODA.

General Characters.—In their structure and habits the animals forming this class present a considerable advance upon the other *Mollusca*—an advance so great, in fact, that by several zoologists they have been regarded as forming a distinct primary division of the animal kingdom. This view is supported by the presence of a rudimentary cartilaginous cephalic skeleton in these animals, and also by a peculiarity in the development of the embryo, which is not effected as in the other *Mollusca*.

Their most striking character is afforded by the locomotive organs, which consist of a circle of tentacles, or arms, arranged round the head, and furnished on their inner surface with numerous sucking-cups, which enable the animal to take a firm grasp of any object (Fig. 286). By means of these arms the *Cephalopoda* creep along the bottom of the sea with the head and mouth downwards; they also serve for the capture of prey—these animals being very carnivorous in their habits. They also swim rapidly by the expulsion of the water from the branchial chamber.

The branchiæ in the *Cephalopoda* are placed on both sides of the body, which is short, thick, symmetrical, and not rolled in a spiral form. The shell is often spiral; but the portion inhabited by the animal is divided from the rest by a transverse partition; so that, by the successive growth of the animal, the shell acquires a chambered structure. The body is inclosed in a sac-like mantle, which is open in front on the ventral surface for the passage of water into the branchial chamber; this is again expelled, by muscular action, through a separate siphon, placed a little in advance of the incumbent orifice. The gills (Fig. 287) are plumose organs, formed of numerous laminae attached to the sides of a central stalk, through which the blood passes to them. At the base of each gill is a pulsating cavity, which drives the blood through these organs; and this fluid is received in another cavity on its return from the gills, and by the contraction of this is driven into the central heart.

The mouth is armed with a pair of powerful horny jaws, presenting a considerable resemblance to the beak of a parrot, within which is a fleshy tongue, part of which is covered with recurved spines. The intestines are convoluted, and the anus opens into the exhalant siphon; the liver and salivary glands are very large.

In the development of the nervous system (Fig. 6), the *Cephalopoda* exhibit a great advance upon the other *Mollusca*. The cephalic portion is very large, and composed of several ganglia, closely united together; the œsophagus, as usual, passes through the ring formed by the subœsophageal ganglia. The brain is surrounded by a cartilaginous ring, the first indication of an internal skeleton, which also usually gives off processes for the support of the eyes. The latter organs are of large size, placed on the sides of the head, and resemble those of fishes in many respects. The auditory vesicles, with their otoliths, are also imbedded in the cartilaginous ring. Two small cavities, in the neighbourhood of the eyes, are supposed to be organs of smell; and, as we have already seen that the tongue is a fleshy organ, it appears probable that the *Cephalopoda* possess all the senses in a state of considerable perfection.

The skin is generally thick and leathery, but covered with a delicate cuticle, in which numerous cells of different colours (*chromatophora*) are inclosed. The animal possesses the power of altering the position of these cells; so that the tint of the skin is constantly changing; this effect continues even for some hours after death, and furnishes the inhabitants of those countries, where the Cuttle-fishes are eaten, an excellent means of judging of the freshness of the fishmonger's commodities.

A peculiar organ possessed by many *Cephalopoda* is the ink-bag, a small pyriform sac inclosed in the visceral cavity, which secretes a dark brown fluid; it communicates by a duct with the exhalant siphon, and through this its contents may be discharged into the water, which is thus discoloured for a considerable extent. When attacked, the animals constantly employ this artifice to facilitate their escape, the inky secretion producing a thick cloud in the water, under cover of which the Cuttle-fish rapidly retreats to a safe distance from the object which has excited his apprehensions. This fluid was formerly employed in the arts, and gives its name to the well-known colour denominated sepia (*Sepia*, a Cuttle fish); but a considerable portion, if not the whole, of the article sold under this name is now derived from other sources. It is remarkable that the ink-bags of Cuttle fishes are often found preserved in a fossil state, although the remainder of the animal is reduced to an almost unrecognizable form.

The *Cephalopoda* are all unisexual animals; their ova are usually of large size. The sexes are generally very similar in appearance; but in some species males of a very peculiar form have been observed, which, at their first discovery, were regarded as parasitic worms, and described under the generic name of *Hectocotylus*. They are worm-like creatures, furnished with a double row of sucking-cups, which give them a close resemblance to a detached arm of a perfect animal. On the surface opposite to these suckers they are provided with filamentous branchiæ in some species; but these are wanting in others. They are generally found adhering to the siphon of the female, but sometimes attach themselves to the arms of their partner, upon which they creep about rapidly by the assistance of their suckers.*



Fig. 346.—Embryo of a Cephalopod with yolk sac.

We have already stated that a difference exists between the *Cephalopoda* and the other *Mollusca* in the mode of development of the embryo. In the latter, the entire yolk becomes converted into an embryo; in the *Cephalopoda*, on the contrary, the first rudiments of the young animal make their appearance at a particular portion of the surface of the yolk, so that the development of the embryo takes place exterior to this body, which gradually disappears as the young Cephalopod approaches maturity.

Divisions.—The *Cephalopoda* are divided into two orders, characterised by the number of their branchial plumes, of which there are either one or two on each side.

ORDER I.—TETRABRANCHIATA.

General Characters.—This order, which includes a vast number of fossil forms (*Ammonites*, &c.), is represented in our seas only by the *Nautili*, of which a few species still inhabit the seas of tropical regions. They are all inclosed in a shell, divided by transverse partitions into a number of chambers (Fig. 347), gradually increasing in size towards the mouth of the shell, where a considerable space is left for the habitation of the animal. As the latter grows, and increases the size of its shell in the usual manner, by additions to the mouth, it, at the same time, cuts off a portion of the space it formerly occupied by a fresh partition; thus adding another chamber to its residence. The partitions are traversed, either in the centre or close to the wall of the shell, by apertures, through which passes a vascular *siphuncle*, communicating with the chamber in which the heart lies. The remainder of the chambers is filled with air. In the recent *Nautili*, and in many fossil species, more or less allied to

* According to the observations of H. Müller, the *Hectocotylus* of the Argonaut is developed in the place of one of the arms of the male.

these, the partitions are of a plain, cup-like form, with the concavity directed towards the mouth of the shell; but in many fossil forms (such as the Ammonites, Fig. 348, and their allies) the partitions are folded towards the edges into various singular forms; and as the thin shells of these creatures are often entirely abraded, so that the fossil is merely a cast of the interior, these patterns are frequently very distinctly visible, and their variations then afford excellent characters for the discrimination of the species.

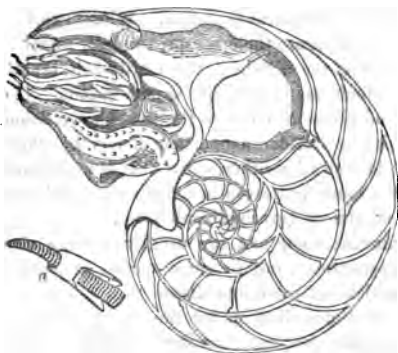


Fig. 347.—Section of Nautilus, with the animal.
a, portion of a tentacle.

sheathes; and instead of being furnished, as in the ordinary *Cephalopoda*, with sucking-cups, are slightly annulated (Fig. 347 a). The branchiae are four in number, placed two on each side of the body.

The animal of the *Nautilus*, the only one with which we can now be acquainted, usually creeps, mouth downwards, along the bottom of the sea; it is sometimes, how-

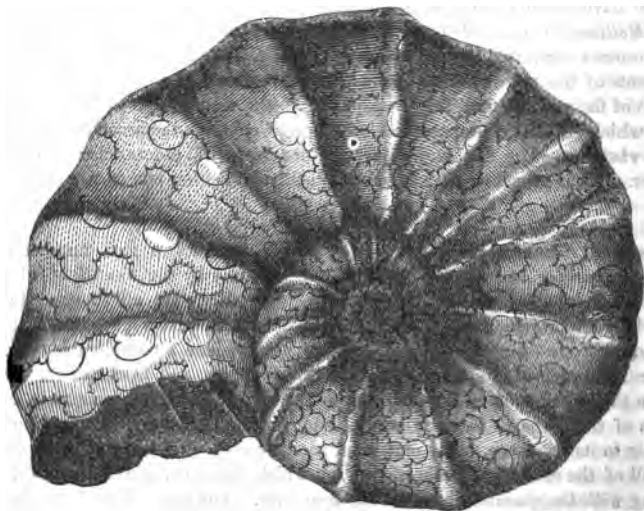


Fig. 348.—Ammonites nodosus.

ever, dislodged from this situation by storms, when it has been seen to float on the surface in a reversed position, with the tentacles expanded. An opinion has very

generally prevailed that this was, in reality, the favourite position of the *Nautilus*, and that its chambered shell was intended to give it the buoyancy necessary for this purpose. This, however, is contradicted by observation; and it appears that the empty chambers only serve to approximate the specific gravity of the animal as nearly as possible to that of the medium it inhabits.

Divisions.—The *Tetrabranchiata Cephalopoda* form two families,—the *Nautilidae* and the *Ammonitidae*. The former, which includes the only living representatives of the order, is distinguished by the simple structure of the partitions of the shell, and by the central position of the siphuncle. The shell is sometimes spiral, as in the *Nautilus* (Fig. 347); but then always consists of but few turns; sometimes perfectly straight (*Orthoceras*), or merely twisted at the apex in a crosier-like form (*Lituites*, Fig. 349). In the *Ammonitidae* the partitions are bent or folded into various forms, and the siphuncle runs along the outer wall of the shell, which is usually spiral, and composed of numerous whorls. Of the genus *Ammonites* (Fig. 348), upwards of five hundred species are known, and many of these are of great size. In some cases, the shells, although spirally twisted, have the whorls separate; in



Fig. 349.—*Lituites Breynei*.



Fig. 350.—*Turritites*.

other instances (*Baculites*) they are perfectly straight. The genus *Pyroceras* has a straight shell, doubled in the middle, with the two parts closely applied; whilst in *Turritites* (Fig. 350), we have a regular screw-like shell, resembling that of *Turritella*, amongst the *Gastropoda*.

ORDER II.—DIBRANCHIATA.

General Characters.—This order, which includes a great number of living as well as fossil species, is distinguished from the preceding not only by the possession of only two branchia, but also by the general structure of the body, which is adapted especially for swimming rapidly through the water, although the animals are able to creep, with the head downwards, upon the bottom of the sea.

The shell is almost always internal, frequently rudimentary; and when external is never chambered. The arms are only eight or ten in number, furnished with sucking discs; and the body is usually provided with a pair of fins.

Divisions.—The *Dibranchiata* are divided into two principal sections, characterized by the number of their arms.

The *Decapoda* have ten of these organs, of which two (called *tentacles*) are usually



Fig. 351.—*Spirula Peronii*, with its shell.

much longer than their fellows, retractile, of a cylindrical form, flattened and provided with suckers at the extremity. Of these, the *Spiralida* appear to make the nearest approach to the animals of the preceding order, as they are furnished with a chambered shell (Fig. 351), which, however, is almost entirely concealed within the body. These animals inhabit the seas of the warm parts of the world, apparently in great abundance, as their shells are cast upon the shore in profusion; nevertheless the structure and habits of the animal are almost unknown.

In the remaining families the shell is entirely inclosed. In the *Sepiida* it forms a broad calcareous plate, terminating in an imperfectly chambered apex. The shell of one species, the *Sepia officinalis*, is the well-known Cuttle-fish bone of the shops; it was formerly employed in medicine, but is now principally used as *pounce*. The bodies of these animals are usually of a somewhat ovate form, and the fins run along the whole length of the sides of the body (Fig. 352).

In the *Loligida* (*Calamaries* or *Squids*), which are nearly allied to the preceding, the body is almost always of an elongated form, and the fins are broad, and confined to the

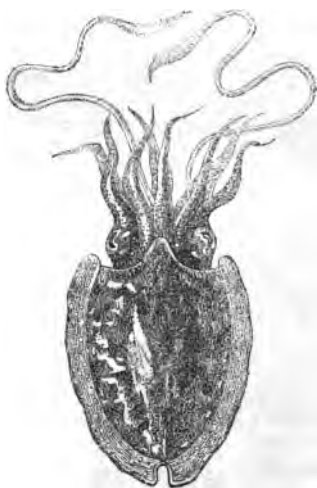


Fig. 352.—*Sepia hieredda*.



Fig. 353.
Pen of *Onychoteuthis*.

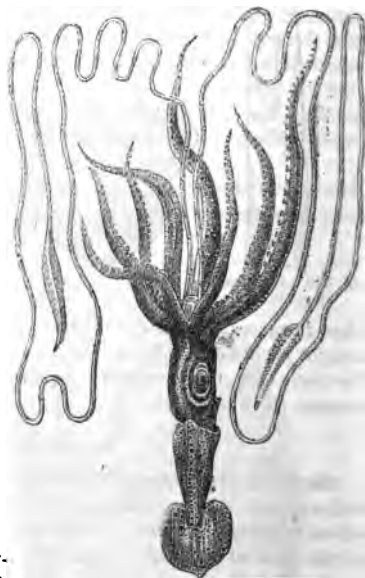


Fig. 354.—*Chiroteuthis bonelli*.

apex of the body. The shell is represented by a horny plate (Fig. 353), which, from its consisting of a central shaft and two lateral expansions, has received the name of the pen. These animals are exceedingly active, and swim well. Their arms are frequently of considerable length, the tentacular arms especially, which in the genus *Chiroteuthis* (Fig. 354) attain no less than six times the length of the body. They are found commonly in all seas. The common British species (*Loligo vulgaris*) is often thrown upon the beach after high winds; and this and other species are much employed as baits in various fisheries.

In the fossil family *Belemnitidae*, the structure of the internal shell is far more complicated. In its general form (Fig. 355) it resembles the pen of the Calamaries, forming a broad corneous plate, which terminates posteriorly in a regularly chambered conical shell (the *phragmocone*), which is furnished with a distinct siphuncle. At its lower extremity, the phragmocone is inserted into the base of a firm, solid, cylindrical sheath, which evidently serves to protect the phragmocone from injury when swimming backwards. From this provision it has been concluded that the Belemnites lived in the neighbourhood of the shores, where they would be in constant danger of coming into collision with fixed objects. From impressions of these soft animals, which have been preserved in some fine grained strata, it appears that they closely resembled the *Loligidae* in form; their arms were furnished with rows of sharp hooks.



Fig. 355.
Belemnite.

The *Octopoda* are distinguished by the possession of only eight arms, without the retractile tentacular arms of the true Cuttle-fishes; they are but rarely furnished with fins. The *Octopodidae* are naked animals, with scarcely any trace even of an internal shell. The arms are united at the base by a broad membrane, which appears to be of great service to the animals in swimming. They are exceedingly active and voracious, preying with avidity upon *Crustacea* and fishes. To this family belongs the common "poulpe" of the Mediterranean (Fig. 356), which is a regular article of food in the south of Europe. The *Octopodidae* not unfrequently attain a considerable size. M. Sander Rang mentions one, which he saw, of the size of a large cask. The tales of navigators attribute still larger dimensions to some of these animals, which have been said to possess arms of thirty, or even sixty, feet in length. From the same authorities it would appear that these giants have a mischievous and very disagreeable

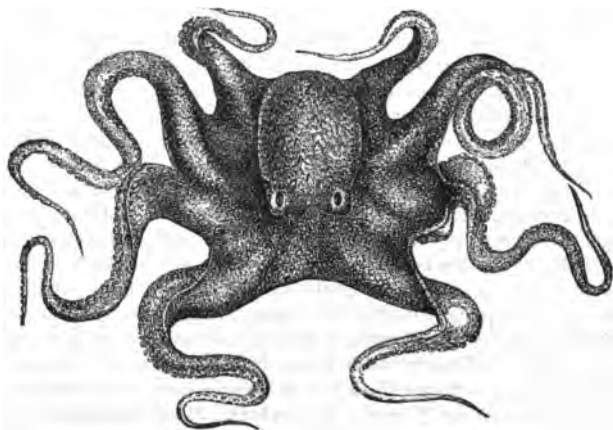


Fig. 356.—Poulpe (*Octopus vulgaris*).

propensity for embracing any passing boat, with their enormous arms, and dragging it down into the deep. To ridicule this idea, Denys de Montfort has represented one of

these monsters in the act of ingulfing a three-master,—an arm being twisted round each of the masts, and reaching nearly to the top! The Kraken of Scandinavian superstition appears to be a still more exaggerated representation of one of these animals. Its existence was gravely alleged by Pontoppidan as the cause of the occasional disappearance of islands!

The *Argonautidae* are furnished with an external shell, the texture of which has obtained for it the name of the *Paper Nautilus*. These animals are remarkable for having two of the arms dilated into broad plates, by the expansion of which, when floating at the surface with its shell reversed, the ancients, and many of the moderns,

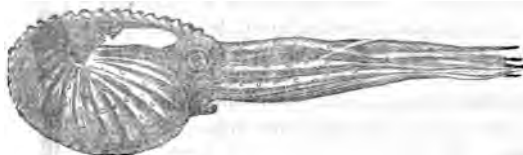


Fig. 357.—Argonauta Argo swimming.

have supposed that the Argonaut sailed gently along in his fragile boat, on the surface of the summer sea. This notion, consecrated as it is by poetical usage, proves to be entirely incorrect. The

Argonaut uses its dilated arms to grasp its shell, whilst swimming backwards, like the other Cephalopods, by the expulsion of water from its branchial chamber (Fig. 357); these organs also appear to secrete the shell, which is not attached to the body of the animal. The male Argonaut is not provided with a shell.

We have thus traced, as fully as our space would permit, the leading characteristics of the vast and varied series of *Invertebrate animals*. Throughout the classification adopted we have endeavoured to represent, as nearly as possible, the generally-received views upon this branch of Natural History, deeming that in a work of this nature, intended for popular instruction, it would be more serviceable to furnish the reader with an intelligible account of the views generally admitted, than to run the risk of communicating erroneous notions by adopting the new and imperfectly developed views which must necessarily prevail during the transition state of any department of science. For this reason we have retained the division of Radiated animals, although, as we have already stated (page 270), the views of naturalists regarding these creatures are in a very unsettled state. The study of these animals is attended with great difficulties. The very nature of many of them is but little known; and we cannot expect that any satisfactory results will be attained until our knowledge of their structure, and especially of their development, shall have made a vast advance.

As it is, however, the classification of the lower animals has made a great advance of late years. The division *Radiata* of Cuvier included a heterogeneous assemblage of animals; and, in fact, with that Zoologist and his successors, served as a repository for anything that could not easily be placed elsewhere. Since the days of Cuvier many of these creatures have been referred to more suitable positions. The entire series of intestinal worms, as well as the *Rotifera*, have been removed to the *Articulata*, and the *Bryozoa* to the *Mollusca*; whilst the entire division of the *Protozoa* is a dismemberment of the Cuvierian *Radiata*. The animals still left in the *Radiata*

division are the *Acalephe*, the *Polypes* (except the *Bryozoa*), and the *Echinodermata* of Cuvier; but the differences between the last-named class and the other *Radiata* are exceedingly great.

An apparently advantageous alteration in the classification of these animals has been proposed by Leuckart and Huxley. These Zoologists separate the Cuvierian *Acalephe* and *Polypes* from the *Echinodermata*, thus forming with them a group which the former denominates *Celenterata*, from the structure of the alimentary organs; the latter, *Nematophora*, from the presence of thread-cells in the skin. According to Leuckart, this group may be divided into three classes, one of which is composed of the Hydroid Polypes, the *Discophora* and the *Siphonophora*; the second of the Asteroid and Helianthoid Polypes; whilst the third includes the *Ctenophora*. The *Echinodermata* must then be regarded as very aberrant forms of the Helminthoid section of the Articulated division; this at least is Mr. Huxley's view; Professor Leuckart has not told us what he proposes to do with the remainder of the *Radiata*.

Of the unicellular constitution of the *Protozoa*, considerable doubts are now being raised; and it seems difficult to reconcile the varied functions performed by these microscopic creatures, with their supposed simplicity of structure. Hitherto, however, authors have generally confined themselves to the expression of doubt; and no satisfactory theory with regard to the constitution of these living atoms has yet been put forward.

There are two phenomena, or rather two modifications of the same phenomenon, to which we must refer in this place, as they are exhibited by members of all the Invertebrate groups of animals. These are *gemmation*, and the so-called "*alternation of generations*;" the latter being only a peculiar modification of the former.

In ordinary gemmation, the original individual produces buds which gradually assume the form of their parent, and are then either thrown off, to lead an independent existence (as in the *Hydra*), or retained in more or less intimate connexion with the parent (as in the compound *Polypes* and *Bryozoa*). We have here, then, an "*alternation*," not of "*generations*," but of "*reproductions*;" the ovum producing a single animal, which produces others exactly resembling itself by a division of its own substance; and all these are equally capable of both sexual and gemmiparous reproduction.

The *process* by which the "*alternation of generations*" is effected, differs in nothing from ordinary gemmation; but the *result* of the process is somewhat different. In the cases to which this name has been applied, the individuals produced by gemmiparity differ more or less from their immediate parents; the functions of sexual reproduction are confined to them, and the ova which they produce give rise to gemmiparous individuals. There is consequently no such thing in nature as an "*alternation of generations*;" and the phenomenon which has been so denominated consists simply in an alternation of gemmiparous and sexual reproduction, in which the offspring of the former process differs more or less from that of the latter.

The observation of these phenomena has introduced considerable difficulty into the realization of the idea of an *individual animal*. We cannot regard every independent animal form as an individual animal, since we know that many of them occur as successive phases in the development of particular species; and on the other hand, it is by no means easy to conceive that these active, independent beings, are merely component parts, or *organs*, of a composite individual. Yet this appears to be the only satisfactory mode of explaining the phenomena in question; and we must therefore regard the whole of the forms produced from a single ovum, until the progeny of that

ovum produce ova in their turn, as so many manifestations of the life of an individual animal. The sum of these manifestations, therefore, makes up the life of the animal. It has been proposed to employ the term *zooid*, to indicate the separate manifestations which, when put together, constitute the *zoön*, or animal individual. The German naturalists have applied the term nurses (*ammen*) to the gemmiparous zooids.

This view may perhaps be rendered clearer by a comparison of the phenomena with those of the metamorphosis of insects. In the latter the egg produces a sex-less individual (*larva*), which undergoes certain changes before attaining its reproductive form; but during the whole of these transformations it still retains its perfect individuality. But if each larva gave rise to one or more sexual forms by gemmation, we should have a case of "alternate generation;" and this really takes place in the *Aphides* (p. 348), if we may regard the viviparous specimens as gemmiparous larval forms.

These phenomena present very different degrees of complication in different species of animals. Thus the individual *Salpa* (p. 423) consists of two zooids, one oviparous, the other gemmiparous; the *Medusa* exhibit a greater complication, the polypes produced from their ova often producing other polypes by ordinary gemmation, from which sexual *Medusa* again take their rise (see pp. 252, 253). The Cestoid worms also consist of two sets of zooids; the embryo is a cystic worm, always furnished with a head, and often producing several heads by gemmation; each head afterwards produces a series of sexual zooids by gemmation, which together form the ordinary Tape-worm (see p. 272). In some *Trematode* worms the individual consists of three zooids: the free-swimming embryo (1) produces a sac-like body (2) by internal gemmation; and this in like manner gives rise to a number of germs, which are converted directly into the sexual zooid (3). In the *Aphides*, as many as eleven consecutive series of gemmiparous zooids have been observed to intervene between two periods of sexual reproduction.

We trust that these remarks, brief as they are, may suffice to furnish the reader with a tolerably clear notion of some of the most interesting phenomena in the Natural History of the lower animals,—phenomena, the correct comprehension of which is of the greatest importance to the student of Zoology.

W. S. DALLAS.

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* Misprinted *Dentia* and *Dents* in the text.

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* Misprinted *Oenothera* in the first.

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